PRELIMINARY HYDRAULICS REPORT
STRUCTURE H-13-N REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
PARK COUNTY, COLORADO

A Part of Section 3, Township 12 South, Range 75 West of the 6th P.M.,
County of Park, Colorado

February 19, 2021

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1. INTRODUCTION

1.1 Background and Purpose

The CDOT Region 2 Bridge Bundle Design Build Project consists of the replacement of a total of nineteen (19) structures bundled together as a single project. These structures are rural bridges on essential highway corridors (US 350, US 24, CO 239 and CO 9) in southeastern and central Colorado. These key corridors provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The design build project consists of seventeen (17) bridges and two (2) Additionally Requested Elements (AREs) structures.

The fourteen (14) of the structures in this design build project are jointly funded by the USDOT FHWA Competitive Highway Bridge Program grant and the Colorado Bridge Enterprise (Project No. 23558). The remaining five (5) structures are funded solely by the Colorado Bridge Enterprise (Project No. 23559). These projects are combined to form one design-build project. The two ARE structures are part of the five bridges funded by the Colorado Bridge Enterprise.

The nineteen bridges identified to be included in the 'Region 2 Bridge Bundle' were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted, limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle is comprised of nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1.2 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure H-13-N as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Park County at Mile Post 240.686 along US 24 just east of Hartsel. Structure H-13-N crosses over the Middle Fork South Platte River. Figure 1 below illustrates the project location. The project is located in A Part of Section 3, Township 12 South, Range 75 West of the 6^{th} P.M., County of Park, Colorado. **Figure 1** shows the project limits.

The report will document preliminary hydrology, hydraulic, and scour analysis/outlet protection to support the proposed structure replacement design.

The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone A, as determined by the Flood Insurance Rate Maps (FIRM) 08093C0750C effective date December 18, 2009, as shown in **Appendix A**. FEMA Zone A is a special flood hazard area inundated by the 100-year flood, however base flood elevations are not determined in a Zone A designation. 44 Code of Federal Regulations (CFR) 60.3 (b) state that for Zone A floodplains, all cumulative impacts to the system from the time of the original study cannot result in a water surface elevation (WSE) increase of more than one foot. This report also reviews changes to the WSE from the proposed bridge design.

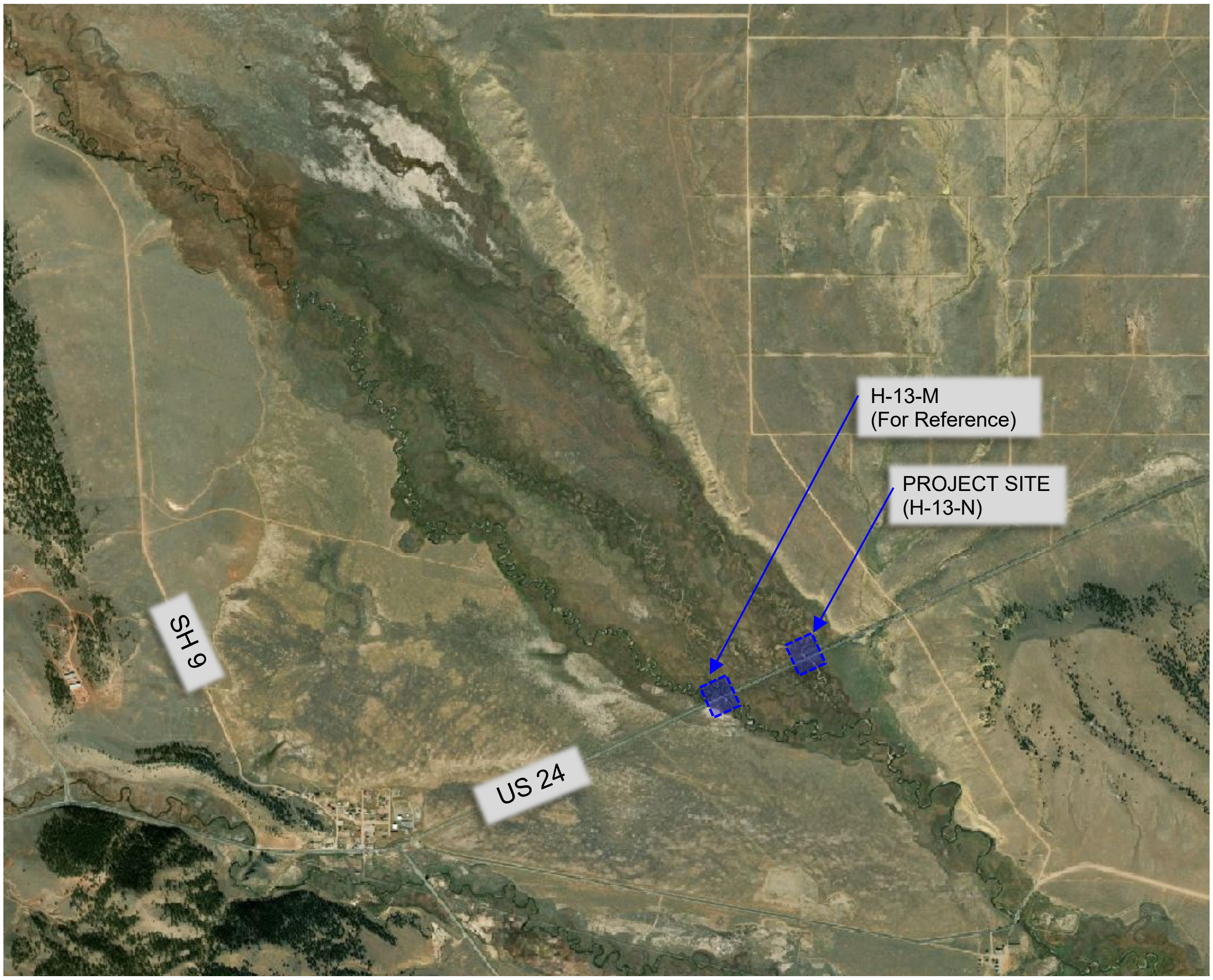


Figure 1: Vicinity Map

2. HYDROLOGY

Preliminary hydrology for the watershed tributary to this structure was done by Stanley Consultants. A memorandum, completed January 11, 2021, has been included with this submittal that summarizes basin areas, runoff methodology and approximate flowrates derived from the preliminary analysis. **Table 1** is a summary of the approximate flowrates within the memo for structures H-13-M and H-13-N.

Table 1: Summary of Peak Discharge for Bridges H-13-M and H-13-N

River Location	Design Storm	Low Flow (cfs)	5-year (cfs)	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	100-year	2,100	2,730	14,745	19,287	26,417

3. EXISTING CONDITIONS

3.1 Existing Structure

Existing structure is a one-span treated timber stringer bridge built in 1937 to span the Middle Fork South Platte River. The bridge does not have skew and was based on a CDOT Standard P-117-B-H. The existing bridge consist of one 23.0 ft span, has a curb-to-curb width of 29.0 ft, and out -to-out deck width of 30.0 ft. The existing vertical clearance varies from 6.0 ft to 9.0 ft. The existing bridge framing consists of 14 rows of 6 in x 20 in wood stringers spaced at 2 ft 3.25 in. The bridge deck consists of 3 in x 6 in wood planks.

3.2 Watershed Overview

The watershed tributary to the river at the US 24 crossing is approximately 244.6 square miles in area. The watershed generally slopes to the south. The stream bed has a seasonally variable base flow.

The stream flows at an angle of attack of 90 degrees to the existing structure. The area surrounding the bridge is rural with undeveloped land to both upstream and downstream sides of the bridge.

3.3 Site Investigation

A site investigation by Stanley Consultants in August 2020 was performed to gain an understanding of the key hydraulic and geomorphic features of the stream at the project site and of the overall watershed. This investigation found obvious deterioration to both abutments and at the wing walls. Site photos are included in **Appendix D**.

4. HYDRAULIC ANALYSIS

A two-dimensional (2D) hydraulic model was developed using the Sediment and River Hydraulics 2D model (SRH-2D) software developed by the USBR in 2008. A 2D model was chosen to represent this area due to the complexity of the stream and for the preliminary scour countermeasure design. The Surface Water Modeling System (SMS) was used to develop the inputs for the SRH-2D Version 13.0 model, as well as post-process the results. For this analysis, three models were developed:

- Existing Conditions
- Proposed Conditions: Box Culvert Replacement
- Proposed Conditions: Arch Culvert Replacement
- Proposed Conditions: Bridge Replacement

4.1 Debris potential

The potential for debris production and delivery is estimated to be low (minimal) based on guidance from Federal Highway Administration (FHWA) Hydraulic Engineering Circular (HEC) No. 20. The flowchart for potential debris production is presented in Figure 2. The channel banks near the bridge are vegetated with tall grasses and shrubs, and no trees present, as confirmed with the site visit in August 2020. Aerial imagery of the watershed near the bridge is shown in **Appendix C**.

Based on past forest fires throughout the watershed, it was considered to classify the channel as high debris, however that approach was determined to be overly conservative for this watershed.

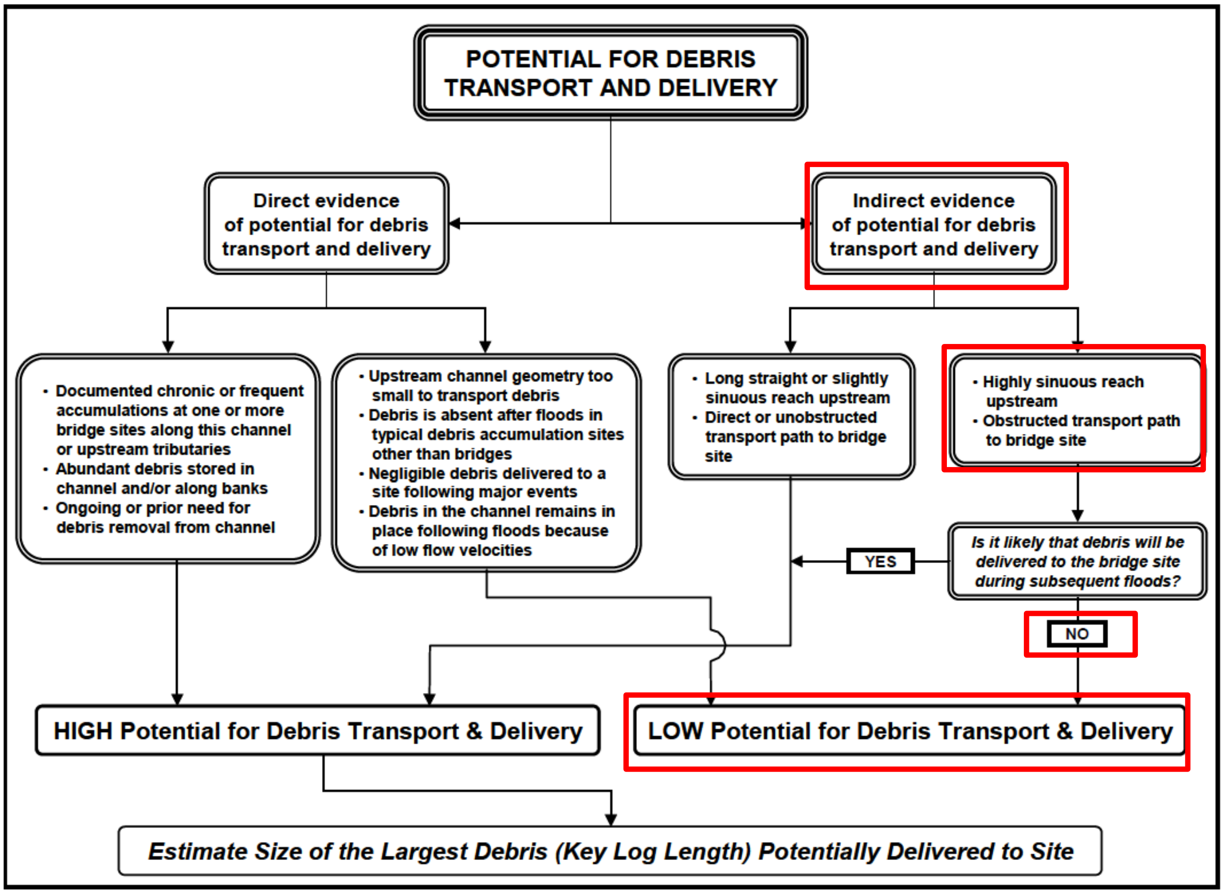


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

4.2 Freeboard

The CDOT Drainage Design Manual (2019) specifies freeboard requirements for all bridges. Freeboard is the minimum clearance between the design approach WSE and the low chord of the bridge. It is a factor of safety that acts as a buffer to account for unknown factors that could increase the height of the calculated WSE. Streams classified as high debris streams shall have a minimum of 4 feet of freeboard. Low-to-moderated streams CDOT highly encourages 2 feet be provided, where practical. The elevation of the water surface 50 to 100 feet upstream of the face of the bridge shall be the elevation to which the freeboard is added to get the bottom or low-girder elevation of the bridge.

The channel was not identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 2 feet of freeboard would typically be required. However, the existing 100-year floodplain overtops the roadway throughout most of the width of the floodplain. Due to funding and site constraints, as well as direction from CDOT, it is not feasible to raise the bridge above the 100-year floodplain. The proposed preliminary design does not increase this condition.

4.3 Modeling Parameters

4.3.1 Elevation Data

Existing conditions survey for the bridge and channel cross sections was performed by CDOT in June 2020. LiDAR was acquired by CDOT in June 2020. These two data sources were combined for the modeling elevation surface.

A local, custom projection was used for the data collection in the existing conditions survey. The survey was converted into NAD 1983 Colorado State Plane Central US Survey Feet for the hydraulic modeling. All elevations are referenced to NAVD 88 (feet).

4.3.2 Computational Mesh

The computational mesh is an unstructured mesh, which allows for the use of triangles and quadrilaterals, with variable element sizes. Roadways used quadrilaterals, with the face lined up perpendicular to flow. Triangles were typically used in the floodplain. The total number of mesh elements is 126,740 and the mesh extends approximately 6,950 feet upstream of the bridge and 1,475 feet downstream of the bridge.

4.3.3 Surface Roughness

Surface roughness, represented by the Manning's roughness coefficient, is presented in **Table 2**. A Manning's n-value was assigned to each land use based on aerial imagery, topography, a site visit in August 2020, and engineering judgement. Photos from the site visit used to confirm the n-values selected are shown in **Appendix C**, and a map showing existing conditions materials coverages is shown in **Appendix D**.

Table 2: Manning's n-values

Land Use	n-value
Channel	0.035
Light Vegetation	0.055
Open Space	0.050
Paved Road	0.016

4.3.4 Boundary Conditions

The boundary conditions include a steady state inflow and a normal depth calculated outflow.

The peak flows developed in **Table 1** were used to develop a steady-state inflow boundary condition. Two inflow boundaries were used for this model. This floodplain spans two structures, H-13-M and H-13-N. H-13-M is not part of this project but was modeled as part of this report. The inflow was separated into the two main channels within the floodplain, one of which flows through H-13-M and the other through H-13-N. The model was set to a dry initial condition.

For the downstream boundary condition, the subcritical outflow option was selected. This outflow condition uses the inputs of anticipated flow, Manning's n-value, channel slope, and terrain data to determine the outflow constant water surface elevation. **Table 3** presents the boundary condition values.

Table 3: Model Boundary Condition Inputs

Frequency Storm	100-year Flow (cfs)	Inflow West (cfs)	Inflow East (cfs)	Outflow Constant WSE (ft)
100-Year	14,745	9,830	4,915	8,228.80

4.3.5 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 8828.24 feet, while the low chord is 8826.04 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

The existing bridge piers were modeled as holes in the computational mesh, allowing flow to run around the piers which replicated true hydraulic conditions.

4.3.6 Simulation Control

The hydraulic simulations are run with a 0.5 second time step for 3 hours when a steady state solution is met. The parabolic turbulence method is used with a coefficient of 0.7.

4.4 Model Results

4.4.1 Existing Conditions

The range of depths experienced in the channel at the bridge during the 100-year event is from 10.54 feet to 11.38 feet. Figure 5 presents the depth for the entire floodplain and the bridge. The results also demonstrate that the existing bridge overtops during the 100-year event. This overtopping depth is 2.65-ft at the lowest point in the roadway. The results show that flows pond behind the embankment as well. Existing conditions 100-year depths of flow are shown in **Appendix D**.

4.4.2 Alternatives Analysis

An alternatives/risk analysis was completed in the preliminary design process to determine the most feasible options for the hydraulic conveyance structure. Three options were analyzed including a reinforced concrete box culvert (RCBC), an arched culvert, and a bridge. Many factors were taken into consideration when determining the preferred alternative for this preliminary analysis. These factors included cost, constructability, effects on the stream hydraulics, environmental impacts, among others.

Per section 7.3.5 of the DDM, the 100-year storm event should be used when sizing a structure conveying flows from a FEMA-mapped floodplain across a roadway. However, because of the current conditions, large flows, roadway grade, and small bridge sizes in this location, it was determined that a structure that would convey the 100-year storm with proper freeboard is not feasible at this time. This box culvert will not meet CDOT requirements for conveyance. It was agreed that this structure would be sized to closely match the current bridge opening, as to not change the floodplain water surface elevations, therefore allowing for a no-rise condition.

Proposed RCBC

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the crossing from 23-ft to 25-ft to accommodate a 2-cell box. The proposed model has 125,636 mesh elements. The use of HY-8 to model this culvert is acceptable due to the direction of flow being perpendicular to the roadway.

Because the existing condition overtops the road, a similar opening size was used for the box culverts to keep the WSEs the same as existing conditions. The preliminary model shows the roadway embankment sloping at 4:1 and the proposed culvert being 43 feet in length. The RCBC option for this structure required a 2 cell 12-foot wide by 6-foot tall structure. This structure size was determined to allow zero rise in the WSEs of the channel. The upstream and downstream invert elevations for the RCBC are both 8819.80 ft.

Depths and velocity grids for the proposed RCBC show depths from 10.77 to 10.83-ft and velocities from 4.71 to 5.69 ft/s. See **Appendix E** for 100-year depths and velocities graphics for this option.

Proposed Arch Culvert

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the crossing from 23-ft to 25-ft to accommodate an arched culvert. The proposed model has 125,636 mesh elements. The use of HY-8 to model this culvert is acceptable due to the direction of flow being perpendicular to the roadway.

Because the existing condition overtops the road, a similar opening size was used for the box culverts to keep the WSEs the same or lower than existing conditions. The preliminary model shows the roadway embankment sloping at 4:1 and the proposed culvert being 43 feet in length. The arched option for this structure required a single ALBC83, which is a corrugated aluminum open-bottom culvert that is approximately 25-ft 2-in wide and 6-ft 8-in tall. This structure size was determined to allow zero rise in the WSEs of the channel.

Depths and velocity grids for the proposed arch show depths from 10.72 to 10.85-ft and velocities from 4.57 to 5.56 ft/s. See **Appendix E** for 100-year depths and velocities graphics for this option.

Proposed Bridge

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the crossing from 23-ft to 25-ft to accommodate the new abutments. The proposed model has 126,604 mesh elements. The proposed model has a 24-foot span width, no piers, the low chord of the bridge is at 8826.0 elevation, and the high chord didn't change from the existing condition. Roadway embankments were graded at 4:1. The bridge option was modeled but was not analyzed. Due to the severe roadway overtopping at this location and the likelihood of other changes to this area in the future a bridge option was deemed not viable for this location.

5. FEMA FLOODPLAIN ANALYSIS

The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone A, as determined by the Flood Insurance Rate Maps (FIRM) 08093C0750C effective date December 18, 2009, as shown in **Appendix A**.

FEMA Zone A is a special flood hazard area inundated by the 100-year flood; however base flood elevations are not determined in a Zone A designation. 44 Code of Federal Regulations (CFR) 60.3 (b) state that for Zone A floodplains, all cumulative impacts to the system from the time of the original study cannot result in a water surface elevation (WSE) increase of more than one foot. This report also reviews changes to the WSE from the proposed bridge design.

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE. Because the opening of the proposed RCBC is about the same as the existing opening, no change in WSE is expected.

In order to perform a comparison between the existing and proposed WSE, 8 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed bridge. The average WSE was determined for both existing and the proposed RCBC option, as shown in **Appendix G**. The WSE comparison at these sections is shown in **Table 4**.

Table 4: Comparison of Existing and Proposed RCBC WSE at H-13-N

Cross Section	Location Relative to Proposed RCBC	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	8863.53	8863.53	0.00
2	Upstream	8854.18	8854.18	0.00
3	Upstream	8843.03	8843.03	0.00
4	Upstream	8832.79	8832.75	-0.04
5	Upstream	8831.22	8831.16	-0.06
6	Downstream	8830.16	8830.16	0.00
7	Downstream	8830.17	8830.17	0.00
8	Downstream	8830.08	8830.08	0.00

Proposed Arch Culvert

Based on modeling results, the proposed arch culvert will not increase the WSE. Because the opening of the proposed arched culvert is about the same as the existing opening, no change in WSE is expected.

In order to perform a comparison between the existing and proposed WSE, 8 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed bridge. The average WSE was determined for both existing and the proposed arch option, as shown in **Appendix G**. The WSE comparison at these sections is shown in **Table 5**.

Table 5: Comparison of Existing and Proposed Arch Culvert WSE at H-13-N

Cross Section	Location Relative to Proposed Arch	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	8863.53	8863.53	0.00
2	Upstream	8854.18	8854.18	0.00
3	Upstream	8843.03	8843.03	0.00
4	Upstream	8832.79	8832.75	-0.04
5	Upstream	8831.22	8831.16	-0.06
6	Downstream	8830.16	8830.16	0.00
7	Downstream	8830.17	8830.17	0.00
8	Downstream	8830.08	8830.08	0.00

6. BRIDGE SCOUR ANALYSIS

6.1 Scour Overview

For the proposed bridge option as determined in the alternatives analysis, a scour analysis was performed for seasonal wash at the arched culvert. The scour analysis is intended to inform the structural design of the crossing and countermeasure design. The FHWA recommends that bridges with complex flow characteristics use a 2D model to represent hydraulic conditions.

For the scour analysis, the FHWA Hydraulic Toolbox Version 4.4 software program was used. The Hydraulic Toolbox program uses equations presented in the FHWA Hydraulic Engineering Circular No. 18 Evaluation of Scour at Bridges (HEC-18) and the National Cooperative Highway Research Program (NCHRP) 24-20. SRH-2D was used as the hydraulic model platform and it has the capability to extract the data needed for these calculations directly from the model.

Based on Table 2.1 from HEC-18 and the conditions of the bridge, the 100-year event is used as the hydraulic design flood frequency, the 200-year event results are used as the scour design flood frequency, and the 500-year results are used as the scour design check flood frequency. Scour was calculated for the 100- and 500-year event for this preliminary analysis.

At the project site, the following scour components were calculated:

- Contraction Scour
- Abutment Scour
- Long-Term Degradation

All scour calculations can be found in **Appendix H**.

6.2 Site Geology/Geotechnical Information and Impact to Scour Depths

A geotechnical analysis was completed Yeh and Associates for the Project. Gradation of the stream bed was provided in this investigation and used for this preliminary scour analysis. Only one sample was taken from the channel, therefore this sample will be applied to abutment (local) scour, contraction scour and long-term degradation. Results from the geotechnical investigation is provided in **Appendix E**.

Borings at each abutment and one at each bridge approach, were also conducted as part of the field exploration. These were used to better understand subsurface conditions at the bridge crossing. Soils information from borings were not used in the scour analysis because boring samples at the abutments were assumed to not be as representative of channel bed conditions as the channel sample discussed above.

Because exact bedrock elevations are not known, no adjustment was made to the scour depths shown below.

6.3 Scour Results

Table 6 below summarizes the preliminary results for scour depths including contraction scour, abutment scour, and long-term scour at the bridge over the seasonal wash. A plot of the total scour is not provided due to the total length of the section spanning the entire floodplain.

Table 6: Scour Analysis Results

	Scour Type (ft)			
Storm Event	**Contraction**	**Abutment (Local)**	**Long-Term Degradation**	**Total***
100-Year	1.4	8.1	0.9	9.0
500-Year	2.9	12.6	1.3	13.9

*Total is the sum of the abutment scour and long-term degradation

6.4 Riprap Scour Countermeasures

The proposed bridge foundations will be designed to withstand the effects of scour up to and including the 500-year Scour Design Check Flood Frequency. Scour countermeasures will be designed to protect the approach roadway and bridge embankments from the effects of scour for the 100-year Hydraulic Design Flood Frequency.

This reach of the river has a wide floodplain that encompasses two separate tributaries that exhibit a high degree of sinuosity. During large flow events the river overtops the roadway in a wide shallow floodplain. These conditions indicate a significant scour potential at this bridge crossing. Vertical wall abutments with wing walls and riprap are recommended as scour countermeasures. The abutment and wing walls shall be designed with riprap extending down to the 100-yr scour depth. The FHWA Hydraulic Toolbox Version 4.4 (FHWA, 2018) was used to size riprap at the ends of the proposed wing walls and along the roadway embankment. The riprap was sized for the 100-year hydraulic design event. The Hydraulic Toolbox applies methodology outlined in the FHWA Hydraulic Engineering Circular No. 23 Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23) for sizing riprap at abutments based on abutment type, set-back ratio, Froude number, specific gravity of rock riprap, and a characteristic velocity in the channel.

Results of the Hydraulic Toolbox analysis are provided in **Appendix H**. A riprap with D50 of 12-inches (in) (Class 3 per HEC-23) is recommended. The resulting recommended thickness is 24-

in based on HEC-23 for Class 3 riprap. Refer to Table 506-2 of CDOT's Division 500 Structures Specifications for the required gradation.

Riprap shall also be placed over a Class 1, non-woven geotextile filter material. According to CDOT's Division 700 Materials Details, geotextile materials should be selected from the New York Department of Transportation's Approved Products List of Geosynthetic materials that meet the National Transportation Product Evaluation Program (NTPEP) and AASHTO M-288 testing requirements. Class 1 geotextiles is the only class approved for applications related to slope protection.

The riprap slope protection should wrap around each abutment and extend 25' from the end of the wing walls along the roadway embankment and be configured with the data shown in **Table 7**. Riprap placed below existing grade shall be constructed with a maximum 2:1 side slope. Riprap above grade will be placed at the roadway embankment slope and no steeper than 2:1.

Table 7: Countermeasure Summary

Countermeasure	D_{50}(in)	Recommended Thickness (in)	Side Slopes	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Top Ref. Elevation (ft)
Riprap	12	24	2:1	9	8810.5	8828.5
Wing Walls	N/A	N/A	N/A	9	8810.5	8828.5

7. RCBC OUTLET ENERGY DISSIPATION

The design procedure recommended in section 11.4 of the DDM was followed for outlet protection and energy dissipation at the outlet of the box culvert. All hydraulic data from the proposed culvert was gathered including height, width, length, slope, etc. The culvert control was determined to be outlet controlled, and outlet depth, velocity and Froude number was determined. To determine tailwater data, the downstream channel information was gathered from the survey data, field inspection, and the SRH-2D model.

Allowable scour estimation was completed using HY-8. Soil parameters of the downstream channel were extracted from the soils reports, and geotechnical investigation. The estimated scour hole was then determined using HY-8. Due to large scour hole estimates, energy dissipation was then considered.

The energy dissipation alternative selected for this RCBC outlet is a riprap apron based on the Froude number of 1.1 which is less than 3. See results from HY-8 energy dissipation analysis in **Appendix H**.

8. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge H-13-N. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary FEMA floodplain analysis and scour analysis.

A two-dimensional model was developed to analyze the flows through the existing bridge and compare the WSEs and velocities to the proposed design. This model was utilized to optimize the proposed solution to replacement of the existing bridge.

Based on the hydraulic analysis, the proposed replacement for this bridge is a single-cell arched aluminum open-bottom culvert, ALBC83, which is approximately 25-ft 2-in wide and 6-ft 8-in tall. The headwater elevation at the culvert entrance is 10.85-ft and the Headwater Depth to Structure Depth (HW/D) ratio is 1.76 at the high point of the arch which does not meet CDOT requirements for a rural two-lane road and FEMA mapped floodplain. This culvert is sized to allow for zero rise in the floodplain WSEs. Variances to the DDM requirements will be required with the final design and approval. CDOT will also be required to develop a Safety Plan for the overtopping that includes signs, maintenance response, etc. that will be reviewed by FHWA.

Floodplain analysis demonstrates that the proposed culvert opening will not cause a rise in flood levels during the 100-year design event. This meets guidelines in CFR Sections 60.3 (b). A floodplain development permit is required to be approved through the Park County floodplain administrator during the final design phase of this Design Build project.

Total design scour for the structure abutments was determined to be 13.9 feet at the 500-year design event and 9.0 feet at the 100-year design event. This accounts for the contraction scour and long-term degradation impacts that could potentially affect the proposed bridge abutments. A riprap apron was designed in order to protect the proposed abutments.

9. REFERENCES

1. "Colorado Department of Transportation Drainage Design Manual", Colorado Department of Transportation, 2019.
2. Mile High Flood District, Urban Storm Drainage Criteria Manual (USDCM), Volumes I, II, and III, August 2018.
3. "Hydraulic Engineering Circular No. 18 – Evaluating Scour At Bridges Fifth Edition". U.S. Department of Transportation Federal Highway Administration, April 2012.
4. "Hydraulic Engineering Circular No. 20 – Stream Stability at Highway Structures". U.S. Department of Transportation Federal Highway Administration, April 2012.
5. "Hydraulic Engineering Circular No. 23 – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance – Third Edition," U.S. Department of Transportation, Federal Highway Administration, September 2009.
6. CDOT Region 2 2D Quick Check Hydrology Summary Report and Matrix, Colorado Department of Transportation, 2020.

APPENDIX A FEMA FIRM 08093C0750C

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table shown on this map. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Floodway Data table shown on this FIRM.

Special Flood Hazard Areas were determined by **approximate study methods**. Therefore, no Flood Insurance Study Report was developed.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713- 3242**, or visit its website at http://www.ngs.noaa.gov.

Base map information shown on this FIRM was derived from NAIP Orthophotography produced with a one meter ground resolution from photography dated 2005.

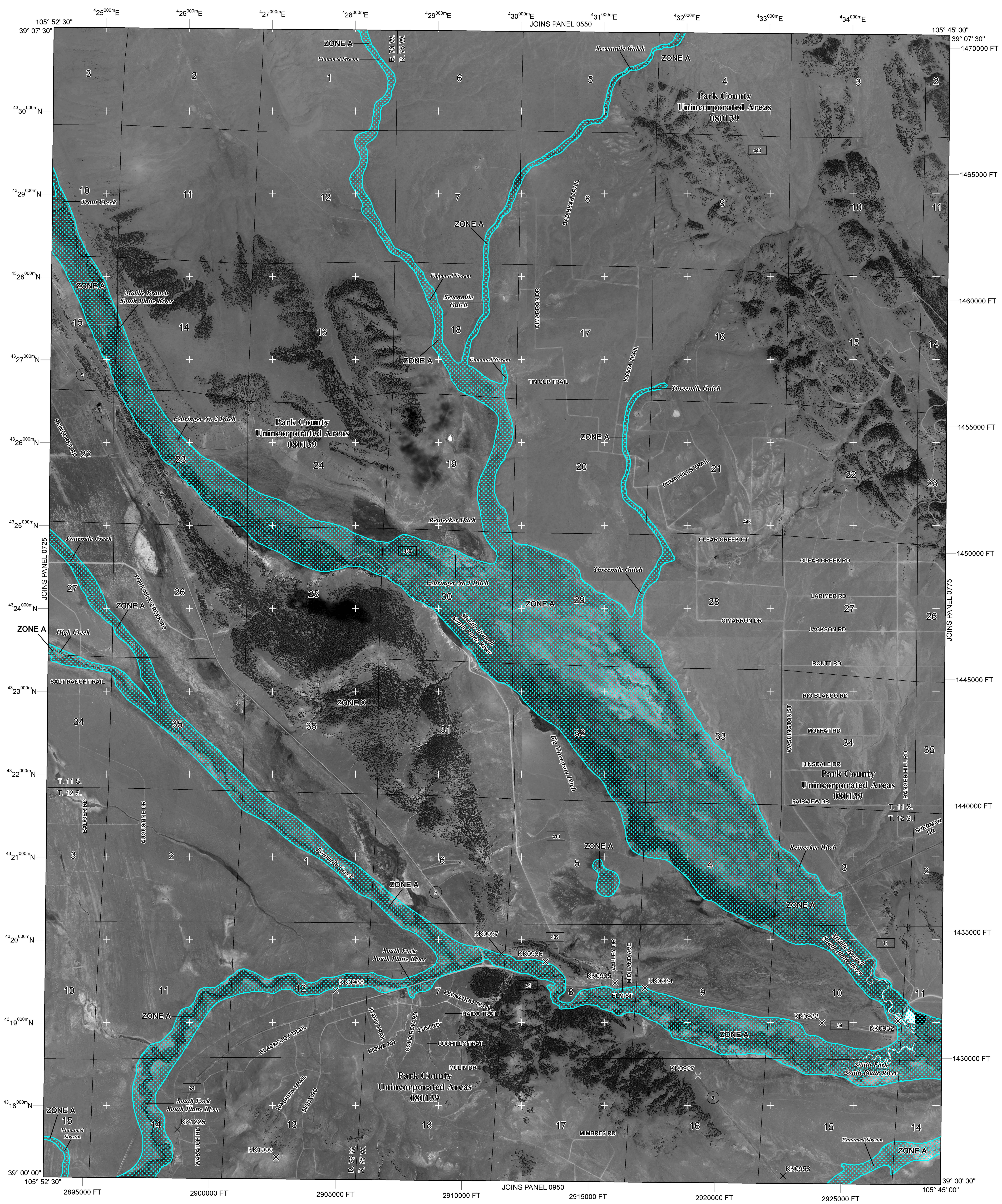
This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables for multiple streams in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and its website at http://msc.fema.gov.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1- 877- FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip/.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	1% Annual Chance Floodplain Boundary
	0.2% Annual Chance Floodplain Boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
~~ 513 ~~~	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

(A)———(A)	Cross section line
(23) - - - - (23)	Transect line
	Culvert
	Bridge
45° 02' 08", 93° 02' 12"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere
3100000 FT	5000-foot ticks: Colorado State Plane Central Zone (FIPS Zone 0502), Lambert Conformal Conic projection
$^{49}89^{000m}$ N	1000-meter Universal Transverse Mercator grid values, zone 13
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
December 18, 2009

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'

1000 0 2000 4000 FEET
600 0 600 1200 METERS

NATIONAL FLOOD INSURANCE PROGRAM

NFIP

PANEL 0750C

FIRM

FLOOD INSURANCE RATE MAP

PARK COUNTY, COLORADO
(AND INCORPORATED AREAS)

PANEL 750 OF 1350
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
PARK COUNTY	080139	0750	C

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08093C0750C

EFFECTIVE DATE
DECEMBER 18, 2009

Federal Emergency Management Agency

APPENDIX B NRCS SOIL SURVEY

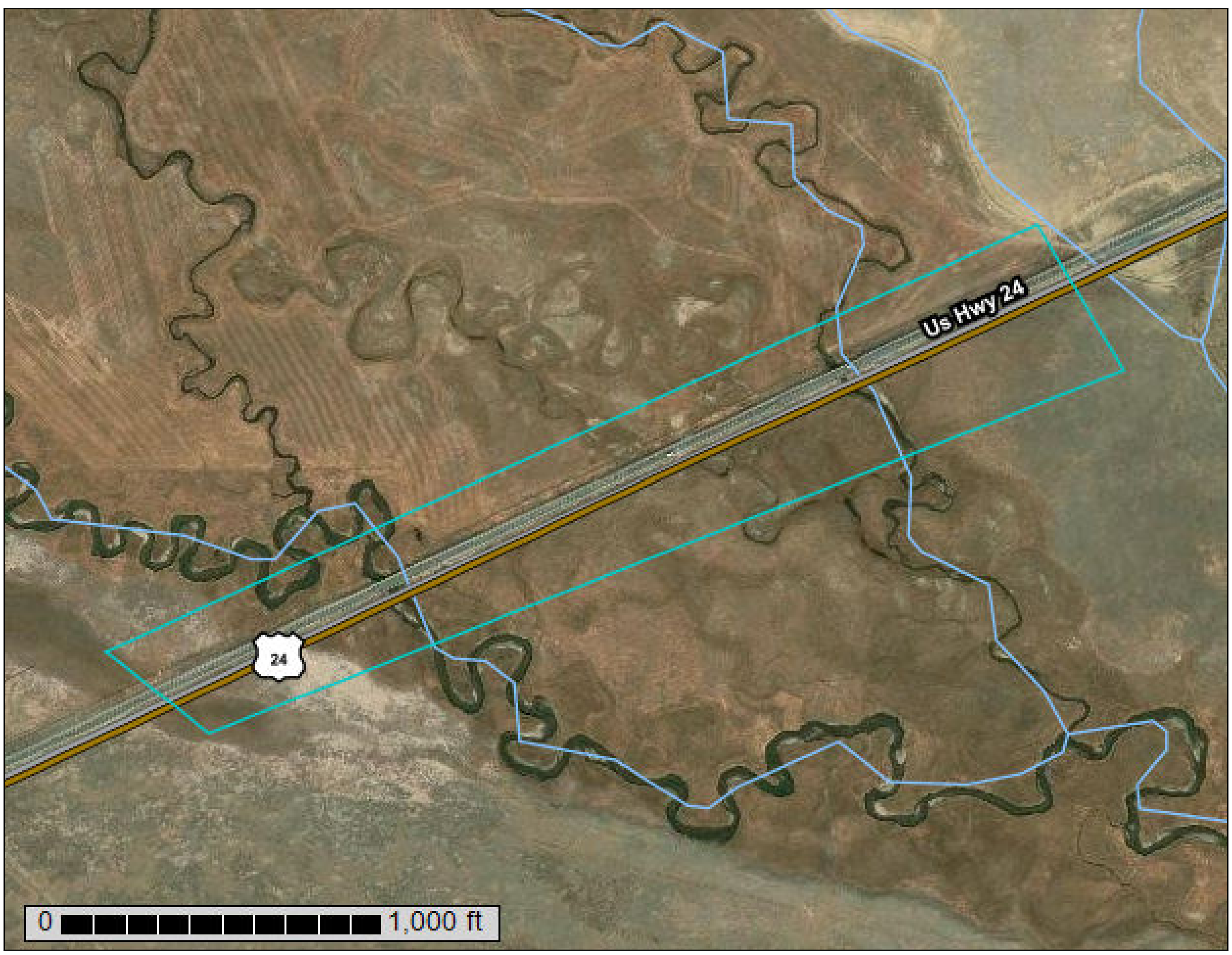
United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Teller-Park Area, Colorado, Parts of Park and Teller Counties



November 17, 2020

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

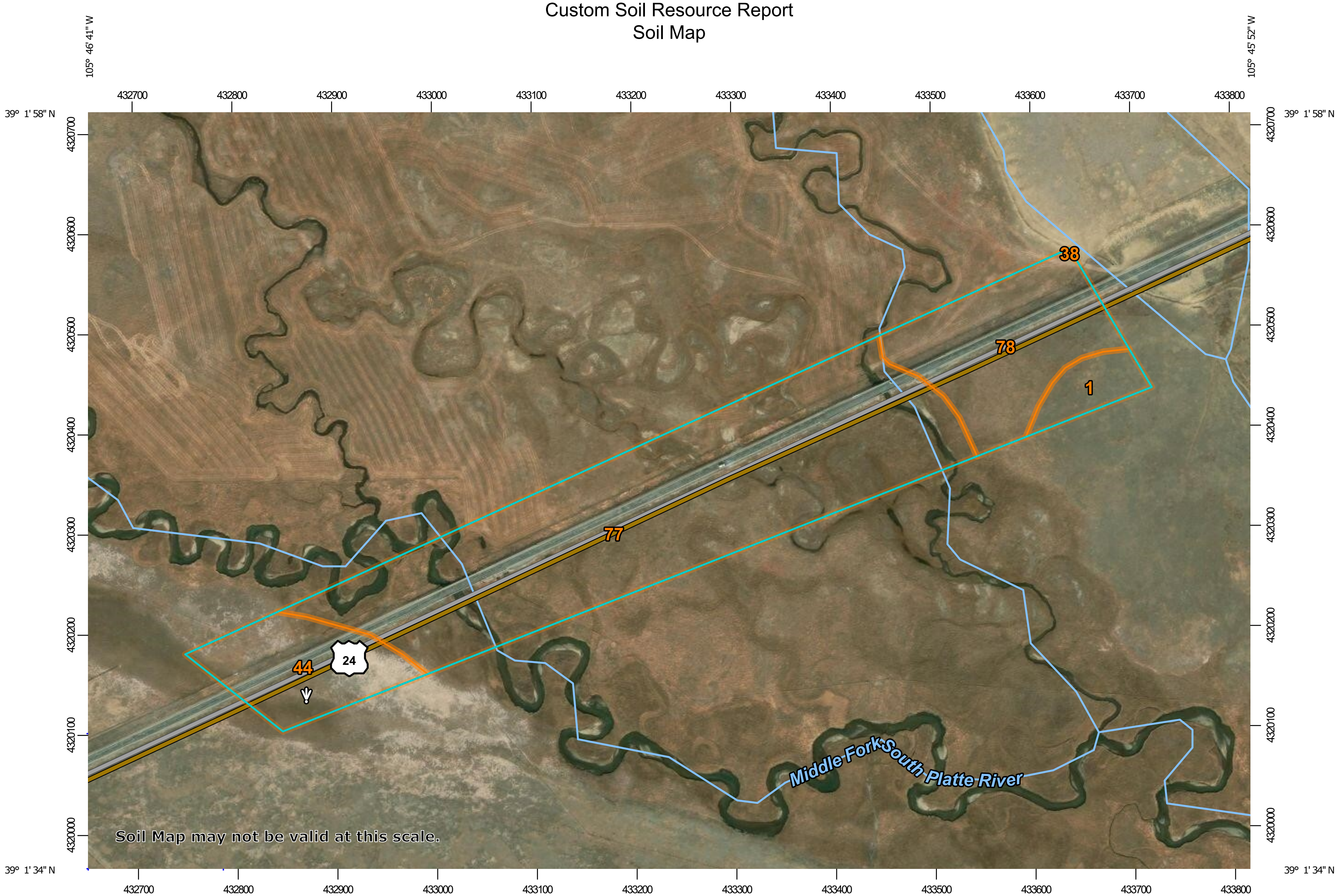
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:5,330 if printed on A landscape (11" x 8.5") sheet.

Meters: 0 50 100 200 300

Feet: 0 250 500 1000 1500

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Teller-Park Area, Colorado, Parts of Park and Teller Counties
Survey Area Data: Version 12, Jun 5, 2020

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 4, 2010—Nov 8, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND	MAP INFORMATION
	imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Adderton loam, 2 to 6 percent slopes	1.3	4.1%
38	Gebson very gravelly loam, 5 to 25 percent slopes	0.0	0.0%
44	Hartbuckle fine sandy loam, 0 to 1 percent slopes	3.9	12.3%
77	Platdon association, 0 to 1 percent slopes	20.5	64.2%
78	Platdon loam, 0 to 1 percent slopes	6.2	19.4%
Totals for Area of Interest		**31.9**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Teller-Park Area, Colorado, Parts of Park and Teller Counties

1—Adderton loam, 2 to 6 percent slopes

Map Unit Setting

National map unit symbol: k0xn
Elevation: 8,000 to 10,200 feet
Mean annual precipitation: 14 to 23 inches
Mean annual air temperature: 37 to 40 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Adderton and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Adderton

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

A1 - 0 to 10 inches: loam
A2 - 10 to 30 inches: loam
A3 - 30 to 42 inches: loam
C1 - 42 to 50 inches: sandy loam
2C2 - 50 to 60 inches: very gravelly sandy loam

Properties and qualities

Slope: 2 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: RareNone
Frequency of ponding: None
Available water capacity: Moderate (about 6.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: B
Ecological site: R048AY222CO
Hydric soil rating: No

Minor Components

Platdon, frequently flooded

Percent of map unit: 10 percent
Landform: Flood plains

Ecological site: R048AY241CO
Hydric soil rating: Yes

Rofork

Percent of map unit: 3 percent
Landform: Mountains
Ecological site: R048AY240CO
Hydric soil rating: No

Bushpark

Percent of map unit: 2 percent
Landform: Mountains
Ecological site: R048AY230CO
Hydric soil rating: No

38—Gebson very gravelly loam, 5 to 25 percent slopes

Map Unit Setting

National map unit symbol: k108
Elevation: 9,000 to 9,300 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Gebson and similar soils: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Gebson

Setting

Landform: Fan remnants, pediments
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium and/or slope alluvium

Typical profile

A - 0 to 4 inches: very gravelly loam
Bt1 - 4 to 7 inches: loam
Bt2 - 7 to 13 inches: loam
Bt3 - 13 to 21 inches: loam
Bk1 - 21 to 30 inches: sandy loam
Bk2 - 30 to 37 inches: sandy loam
Bk3 - 37 to 46 inches: sandy loam
Bk4 - 46 to 51 inches: loam
Bk5 - 51 to 60 inches: sandy loam

Properties and qualities

Slope: 5 to 25 percent

Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Moderate (about 6.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: B
Ecological site: R048BY227CO
Hydric soil rating: No

Minor Components

Temdille

Percent of map unit: 10 percent
Landform: Alluvial fans, bajadas
Ecological site: R048BY227CO
Hydric soil rating: No

Glentivar

Percent of map unit: 5 percent
Landform: Ridges
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Hodden

Percent of map unit: 5 percent
Landform: Breaks
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

44—Hartbuckle fine sandy loam, 0 to 1 percent slopes

Map Unit Setting

National map unit symbol: k128
Elevation: 8,700 to 8,900 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Hartbuckle and similar soils: 90 percent

Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hartbuckle

Setting

Landform: Stream terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

Oa - 0 to 1 inches: highly decomposed plant material
A1 - 1 to 3 inches: fine sandy loam
A2 - 3 to 8 inches: fine sandy loam
Bk1 - 8 to 14 inches: extremely gravelly coarse sandy loam
Bk2 - 14 to 61 inches: extremely gravelly coarse sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 2.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: A
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Minor Components

Hodden

Percent of map unit: 5 percent
Landform: Breaks
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Platdon, frequently flooded

Percent of map unit: 3 percent
Landform: Flood plains
Ecological site: R048AY241CO
Hydric soil rating: Yes

Spinth

Percent of map unit: 2 percent
Landform: Stream terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear

Across-slope shape: Linear
Ecological site: R048BY221CO
Hydric soil rating: No

77—Platdon association, 0 to 1 percent slopes

Map Unit Setting

National map unit symbol: k12q
Elevation: 8,700 to 9,000 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Platdon, poorly drained, and similar soils: 65 percent
Platdon, frequently flooded, and similar soils: 25 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Platdon, Poorly Drained

Setting

Landform: Flood-plain steps
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Alluvium

Typical profile

A1 - 0 to 4 inches: loam
A2 - 4 to 9 inches: loam
AB - 9 to 16 inches: clay loam
Bg - 16 to 22 inches: gravelly loam
2C - 22 to 37 inches: very gravelly loamy coarse sand
2Cg - 37 to 60 inches: extremely gravelly coarse sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: 20 to 31 inches to strongly contrasting textural stratification
Drainage class: Poorly drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 12 to 20 inches
Frequency of flooding: NoneRare
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)

Available water capacity: Very low (about 2.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C/D
Ecological site: R048BY268CO
Hydric soil rating: No

Description of Platdon, Frequently Flooded

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

A - 0 to 8 inches: loam
Ag - 8 to 18 inches: loam
Cg1 - 18 to 30 inches: very gravelly sandy clay loam
2Cg2 - 30 to 60 inches: extremely gravelly sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: 25 to 35 inches to strongly contrasting textural stratification
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 0 to 10 inches
Frequency of flooding: NoneFrequent
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6w
Hydrologic Soil Group: B/D
Ecological site: R048AY241CO
Hydric soil rating: Yes

Minor Components

Spinth

Percent of map unit: 5 percent
Landform: Flood-plain steps
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R048BY221CO
Hydric soil rating: No

Gebson

Percent of map unit: 3 percent
Landform: Hills
Landform position (three-dimensional): Base slope
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park

Hydric soil rating: No

Hartsel

Percent of map unit: 2 percent
Landform: Flood-plain steps
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R048AY241CO
Hydric soil rating: No

78—Platdon loam, 0 to 1 percent slopes

Map Unit Setting

National map unit symbol: k12h
Elevation: 8,700 to 9,000 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Platdon, poorly drained, and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Platdon, Poorly Drained

Setting

Landform: Flood-plain steps
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Alluvium

Typical profile

A1 - 0 to 4 inches: loam
A2 - 4 to 9 inches: loam
AB - 9 to 16 inches: clay loam
Bg - 16 to 22 inches: gravelly loam
2C - 22 to 37 inches: very gravelly loamy coarse sand
2Cg - 37 to 60 inches: extremely gravelly coarse sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: 20 to 31 inches to strongly contrasting textural stratification
Drainage class: Poorly drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)

Depth to water table: About 12 to 20 inches
Frequency of flooding: NoneRare
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 2.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C/D
Ecological site: R048BY268CO
Hydric soil rating: No

Minor Components

Platdon, frequently flooded

Percent of map unit: 5 percent
Landform: Flood plains
Ecological site: R048AY241CO
Hydric soil rating: Yes

Gebson

Percent of map unit: 2 percent
Landform: Hills
Landform position (three-dimensional): Base slope
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Spinth

Percent of map unit: 2 percent
Landform: Flood-plain steps
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R048BY221CO
Hydric soil rating: No

Hartsel

Percent of map unit: 1 percent
Landform: Flood-plain steps
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R048AY241CO
Hydric soil rating: No

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APPENDIX C AERIAL IMAGERY AND PHOTOS

CDOT REGION 2 – BRIDGE BUNDLE

AERIAL IMAGERY AND PHOTOS

STRUCTURE H-13-N

FIGURE 1

AERIAL IMAGERY AND PHOTOS
STRUCTURE H-13-N
FIGURE 2

AERIAL IMAGERY AND PHOTOS

STRUCTURE H-13-N

FIGURE 3

AERIAL IMAGERY AND PHOTOS

STRUCTURE H-13-N

FIGURE 4

AERIAL IMAGERY AND PHOTOS
STRUCTURE H-13-N
FIGURE 5

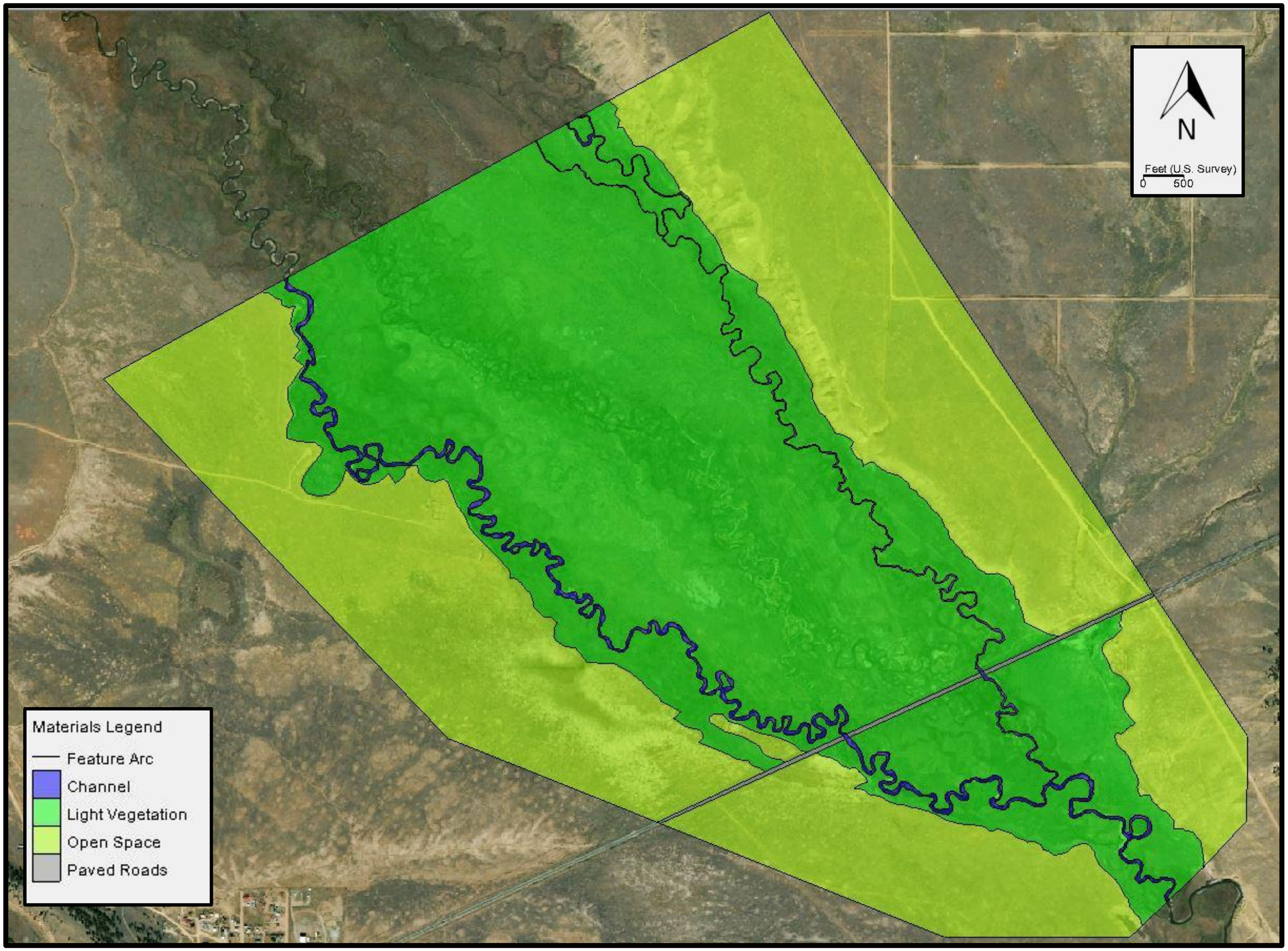
AERIAL IMAGERY AND PHOTOS
STRUCTURE H-13-M (FOR REFERENCE ONLY)
FIGURE 6

AERIAL IMAGERY AND PHOTOS

STRUCTURE H-13-M (FOR REFERENCE ONLY)

FIGURE 7

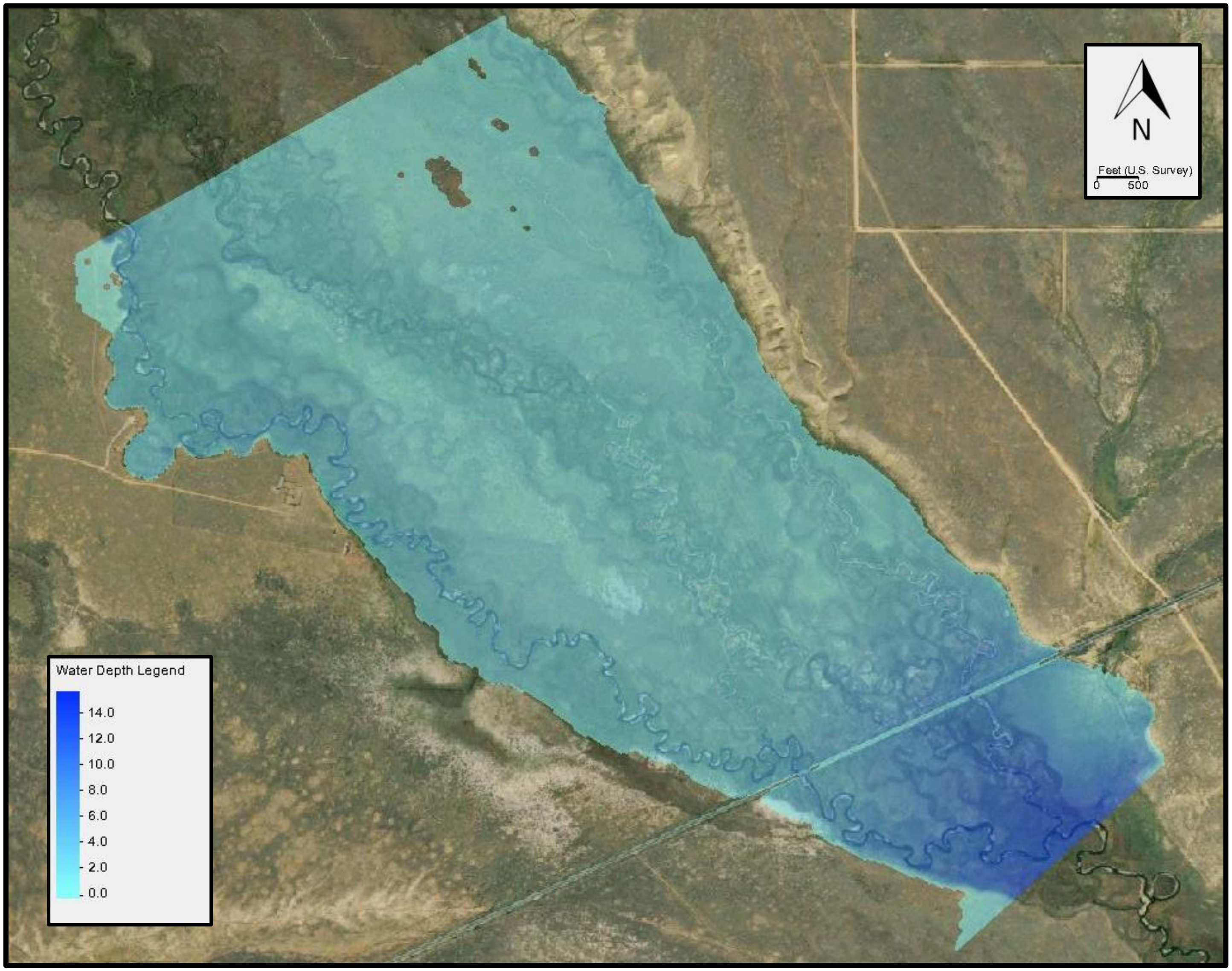
APPENDIX D EXISTING CONDITIONS MODEL GRAHPICS



EXISTING CONDITIONS – MATERIALS COVERAGE

STRUCTURE H-13-N

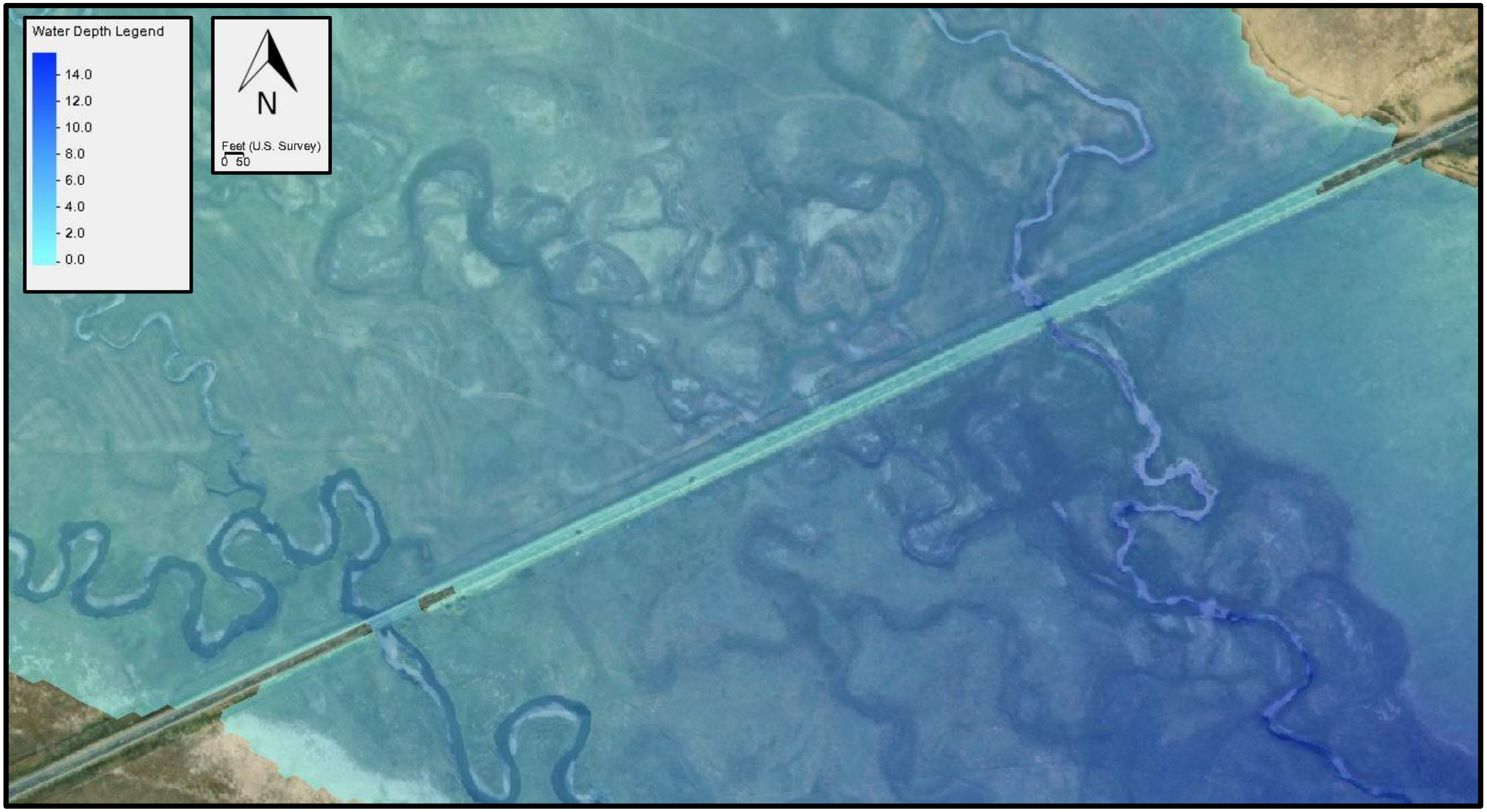
FIGURE 1



EXISTING CONDITIONS – WATER DEPTH

STRUCTURE H-13-N

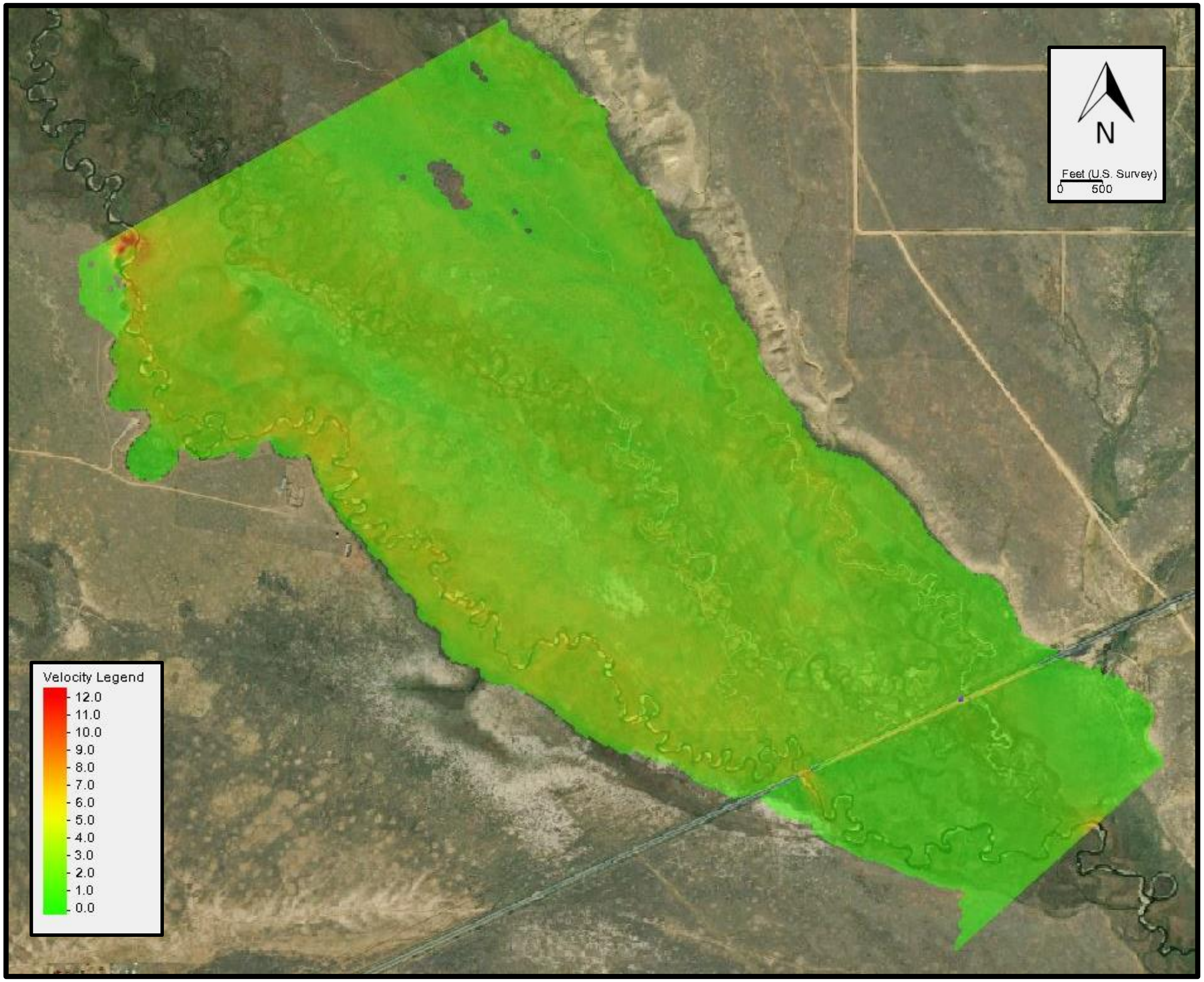
FIGURE 2



EXISTING CONDITIONS – WATER DEPTH

STRUCTURE H-13-N

FIGURE 3



EXISTING CONDITIONS – VELOCITY

STRUCTURE H-13-N

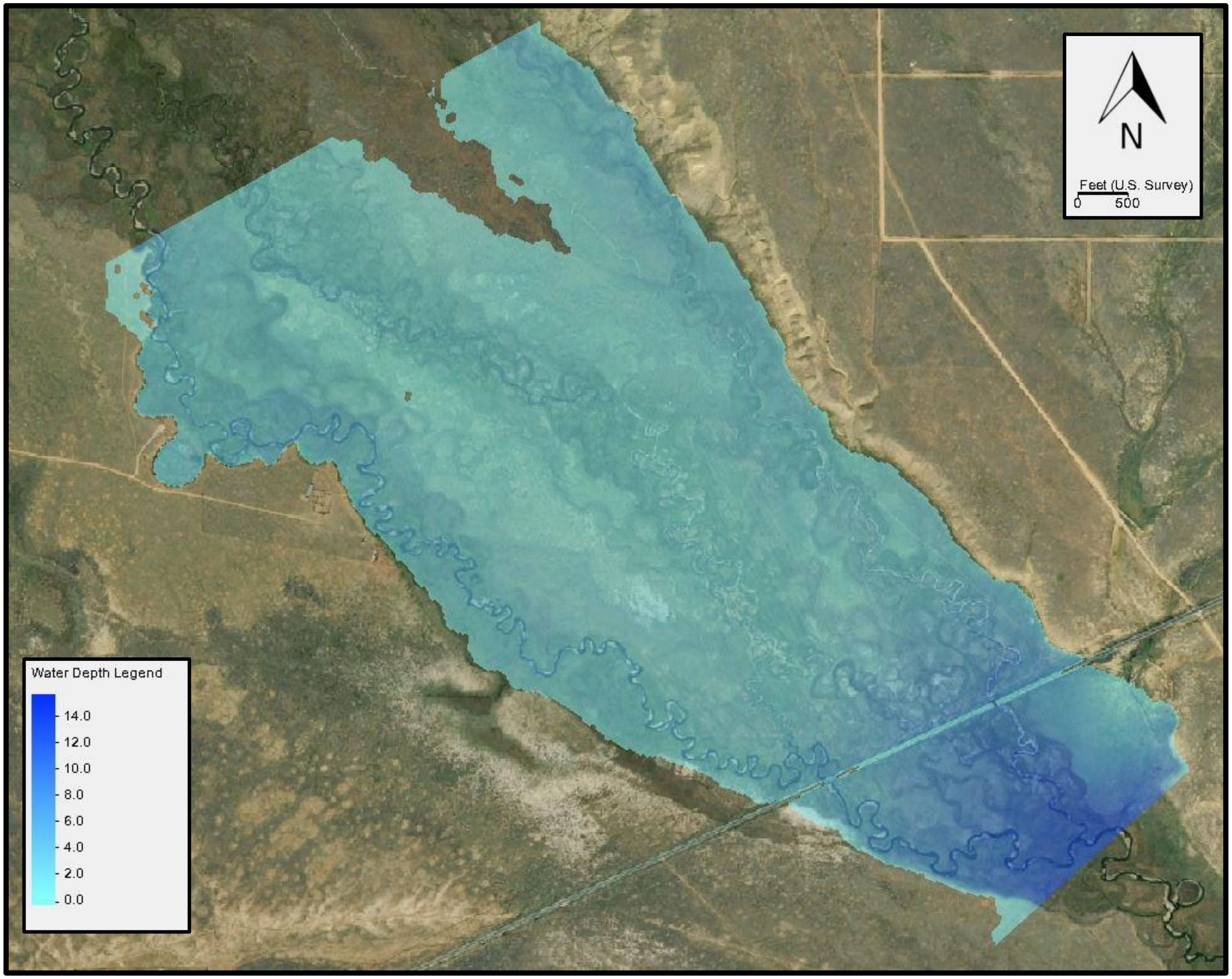
FIGURE 3

EXISTING CONDITIONS – VELOCITY

STRUCTURE H-13-N

FIGURE 5

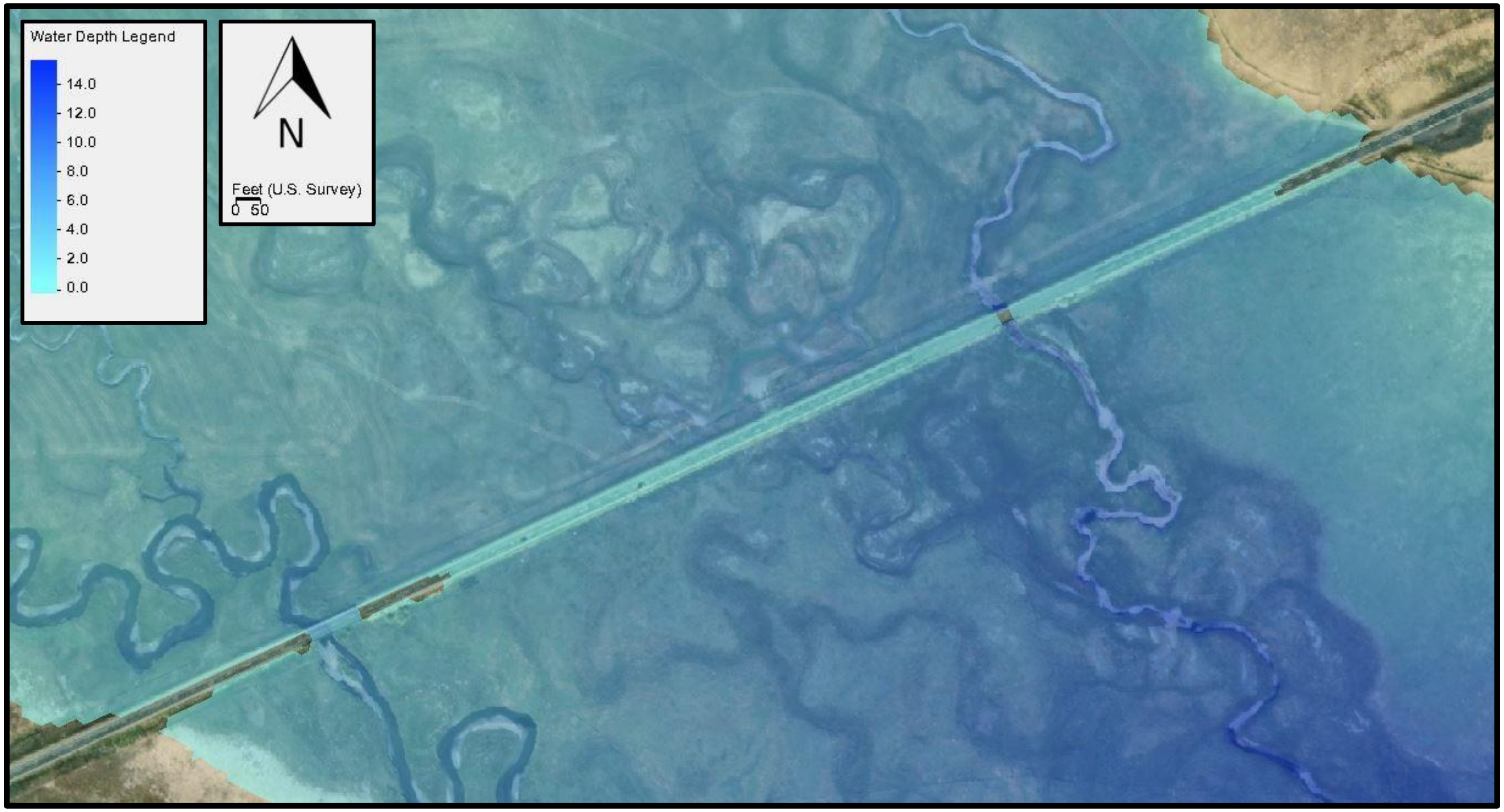
APPENDIX E PROPOSED RCBC ALTERNATIVE MODEL GRAPHICS



PROPOSED CONDITIONS – WATER DEPTH

RCBC AT STRCUTURE H-13-N

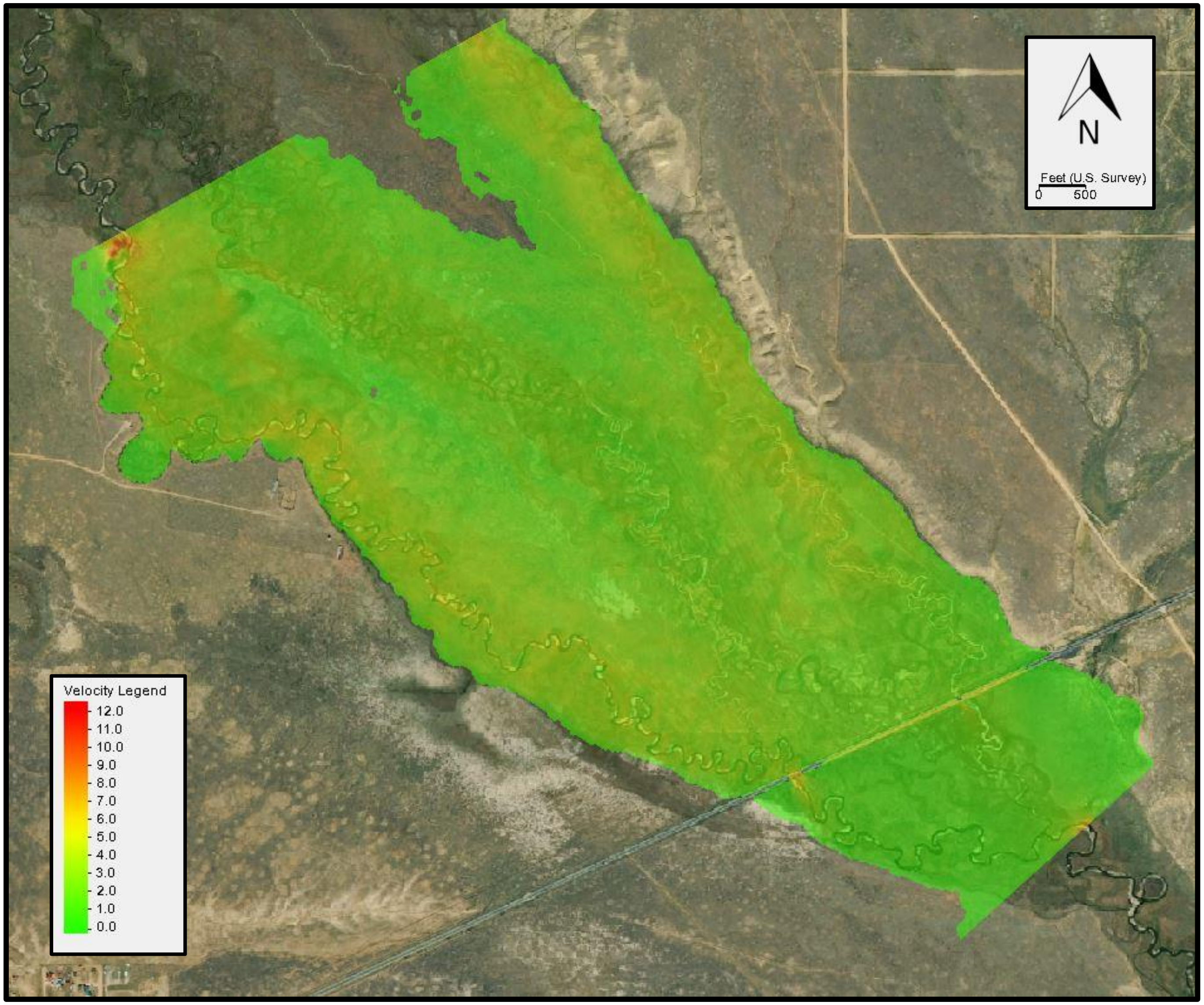
FIGURE 1



PROPOSED CONDITIONS – WATER DEPTH

RCBC AT STRCUTURE H-13-N

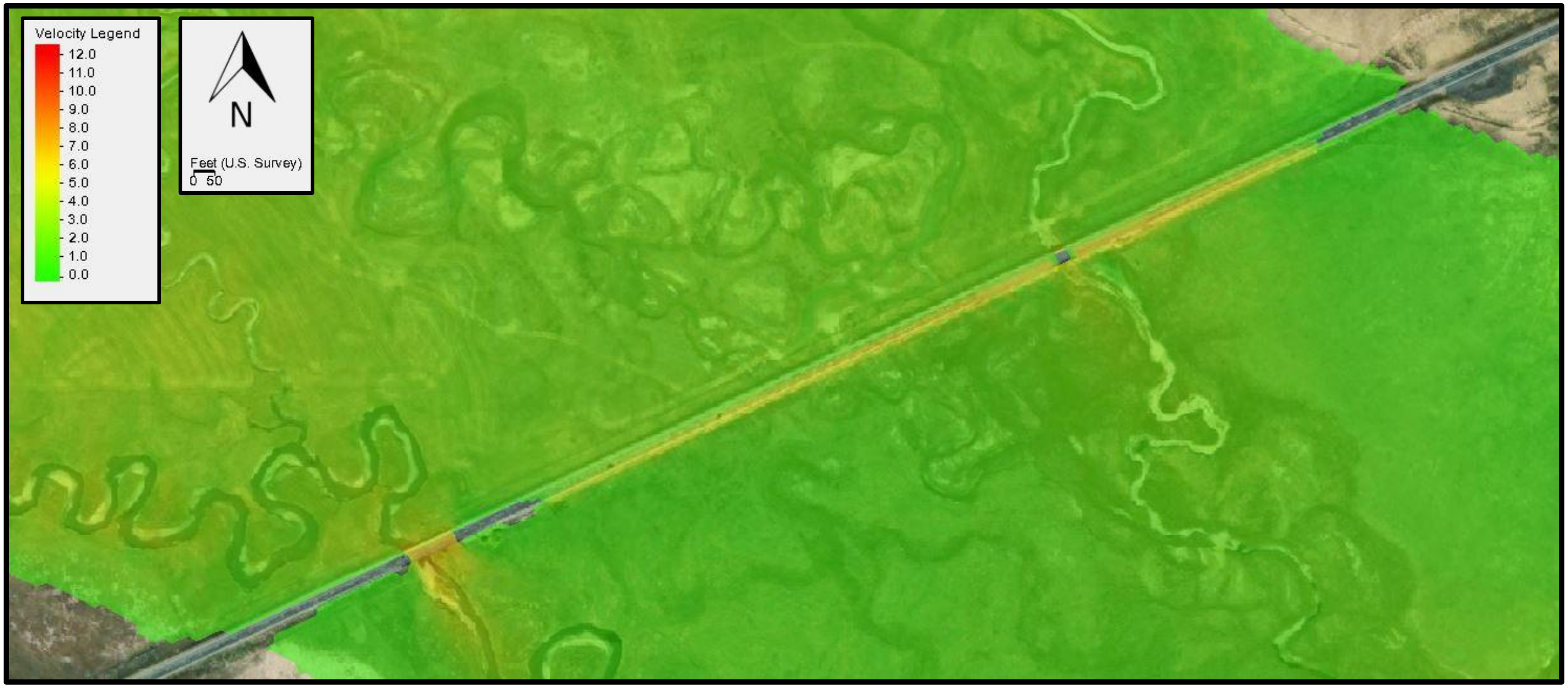
FIGURE 2



PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURE H-13-N

FIGURE 3

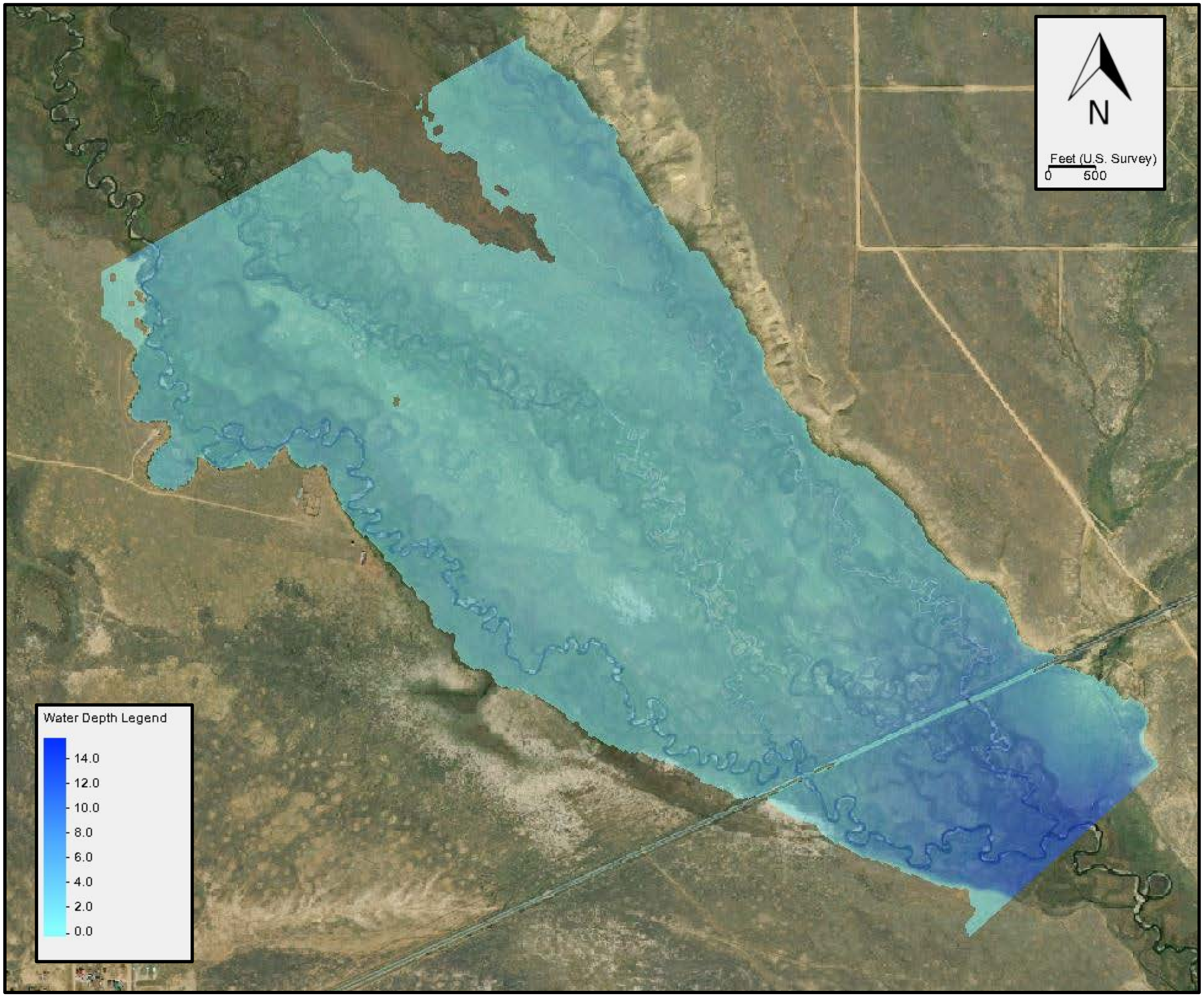


PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURE H-13-N

FIGURE 4

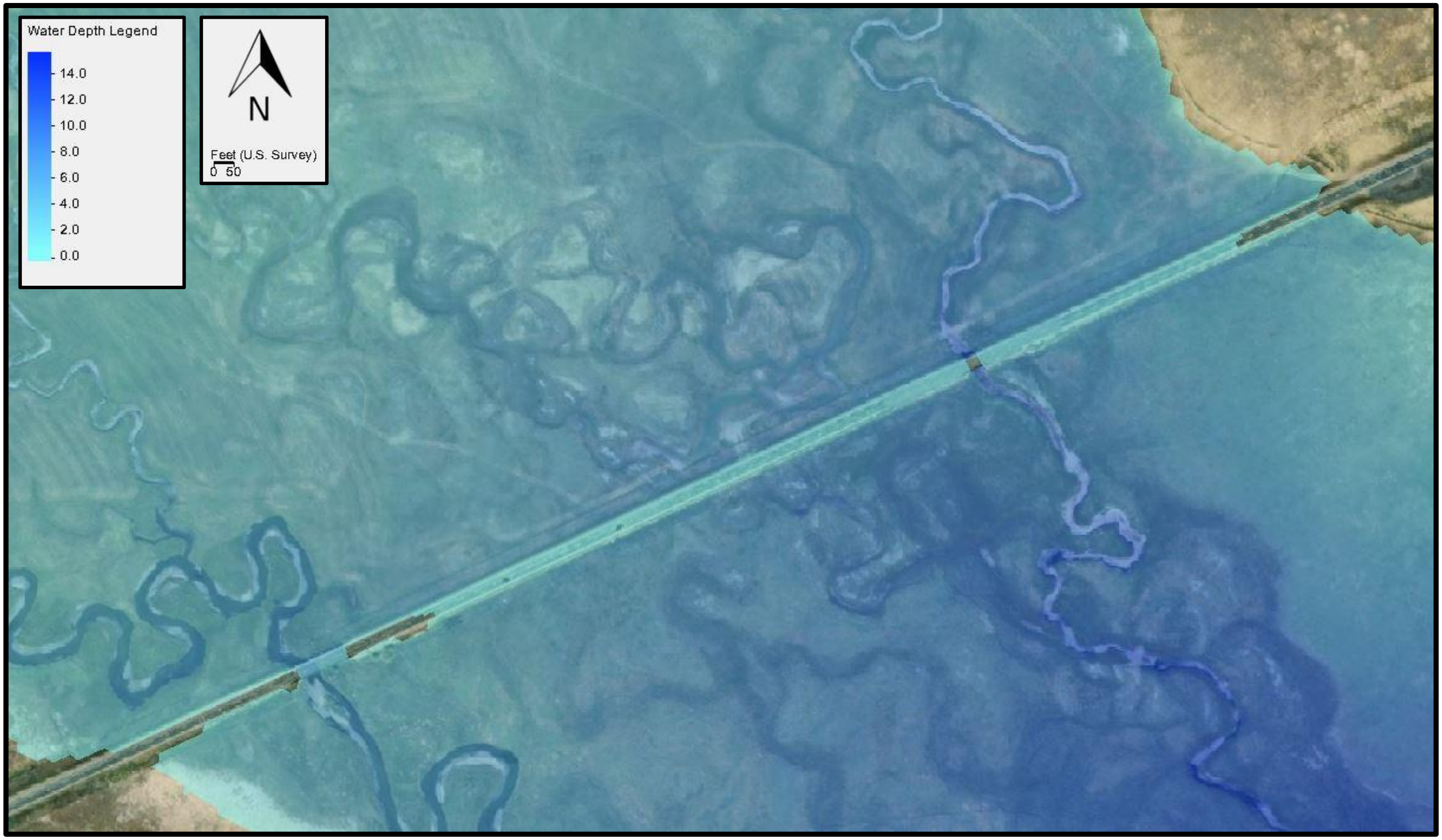
APPENDIX F PROPOSED ARCH ALTERNATIVE MODEL GRAPHICS



PROPOSED CONDITIONS – WATER DEPTH

ARCH AT STRUCTURE H-13-N

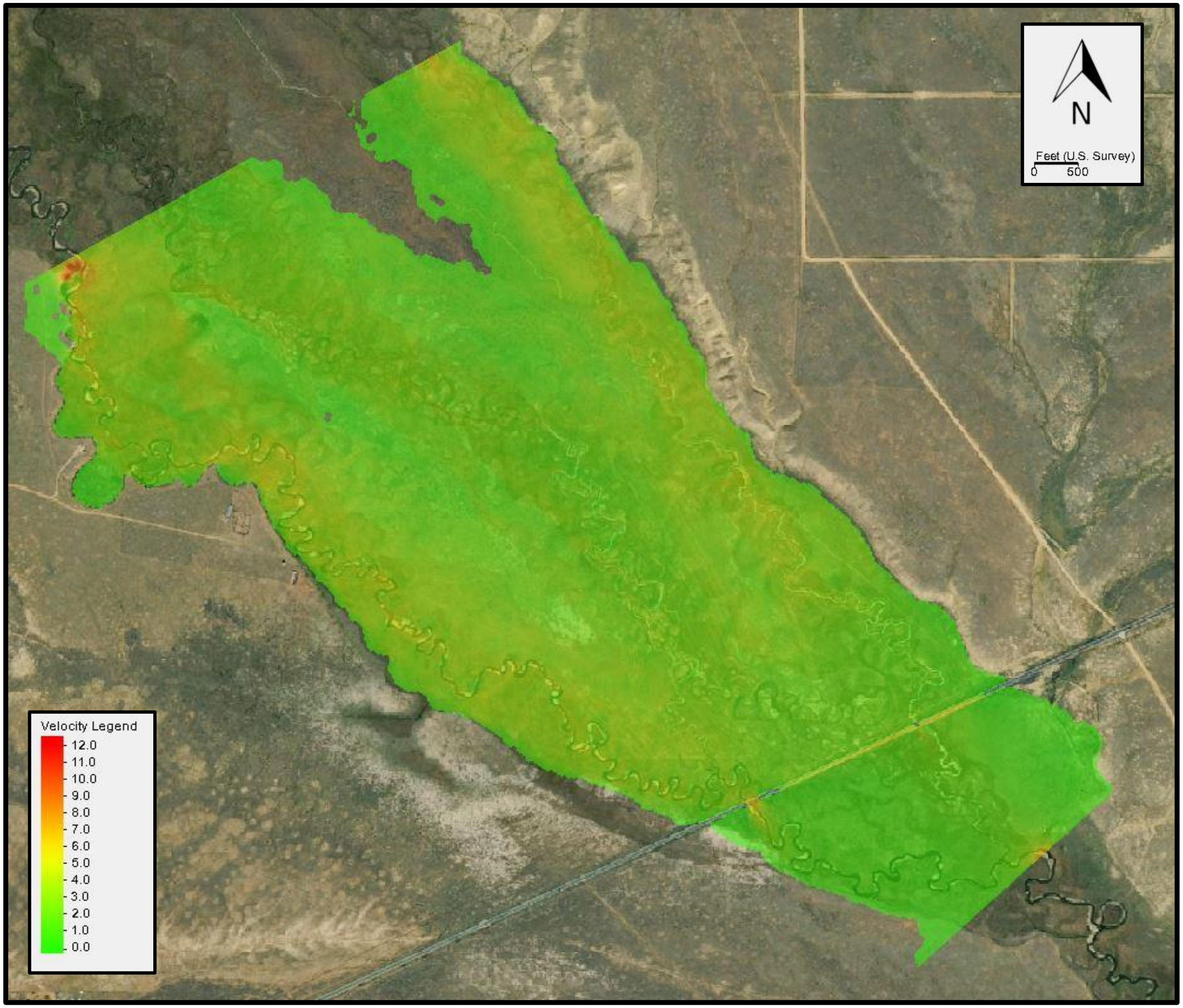
FIGURE 1



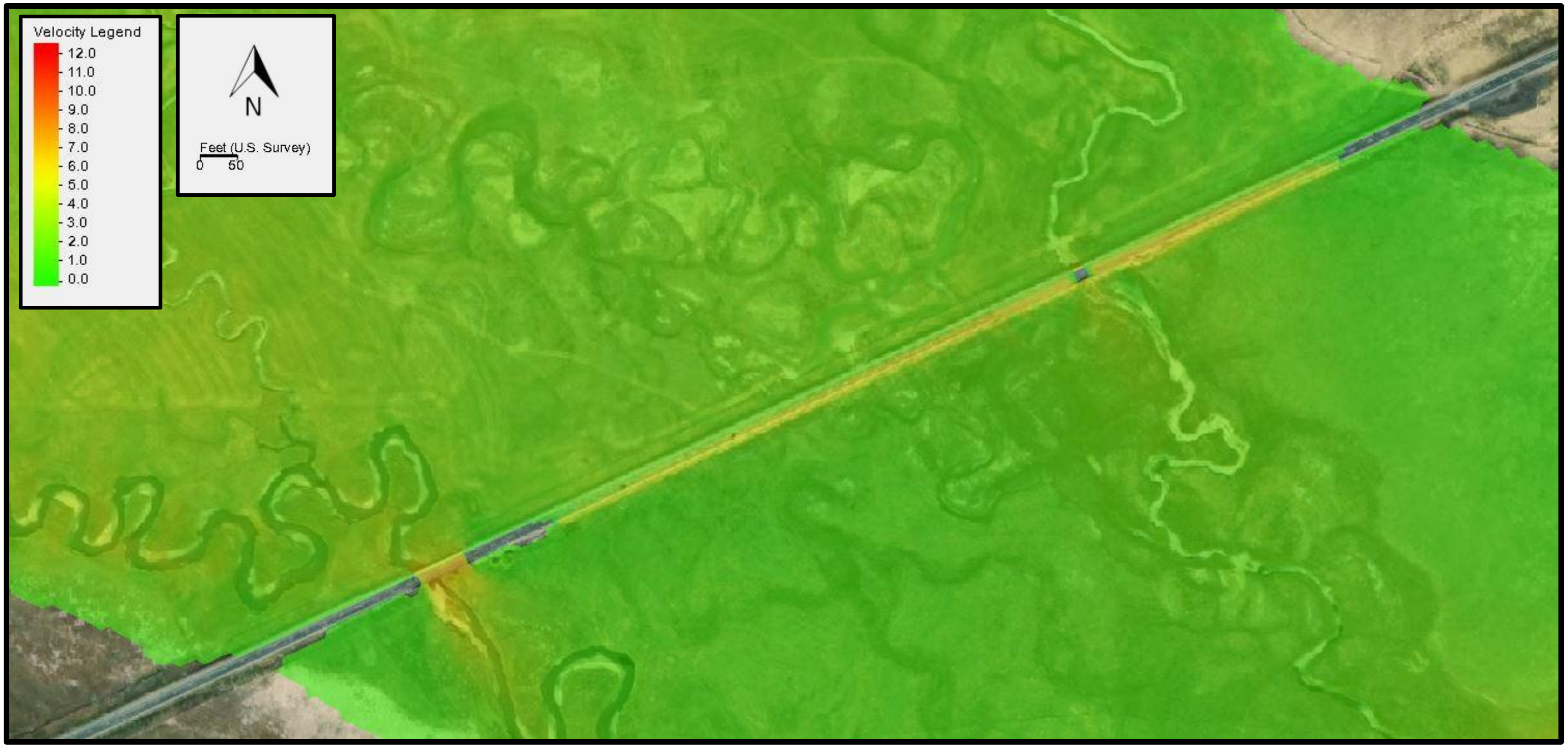
PROPOSED CONDITIONS – WATER DEPTH

ARCH AT STRUCTURE H-13-N

FIGURE 2



PROPOSED CONDITIONS – VELOCITY
ARCH AT STRUCTURE H-13-N
FIGURE 3

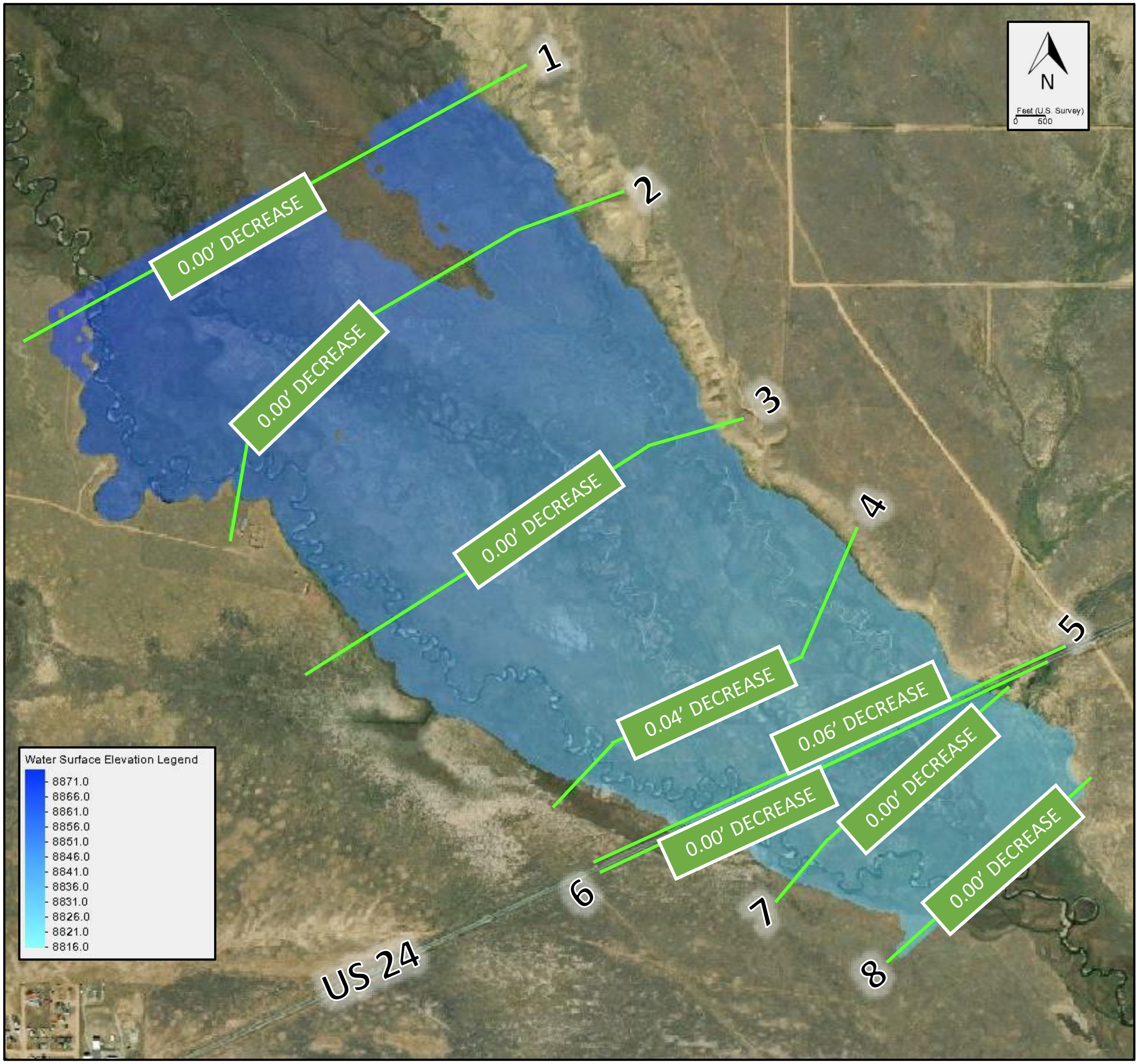


PROPOSED CONDITIONS – VELOCITY

ARCH AT STRUCTURE H-13-N

FIGURE 4

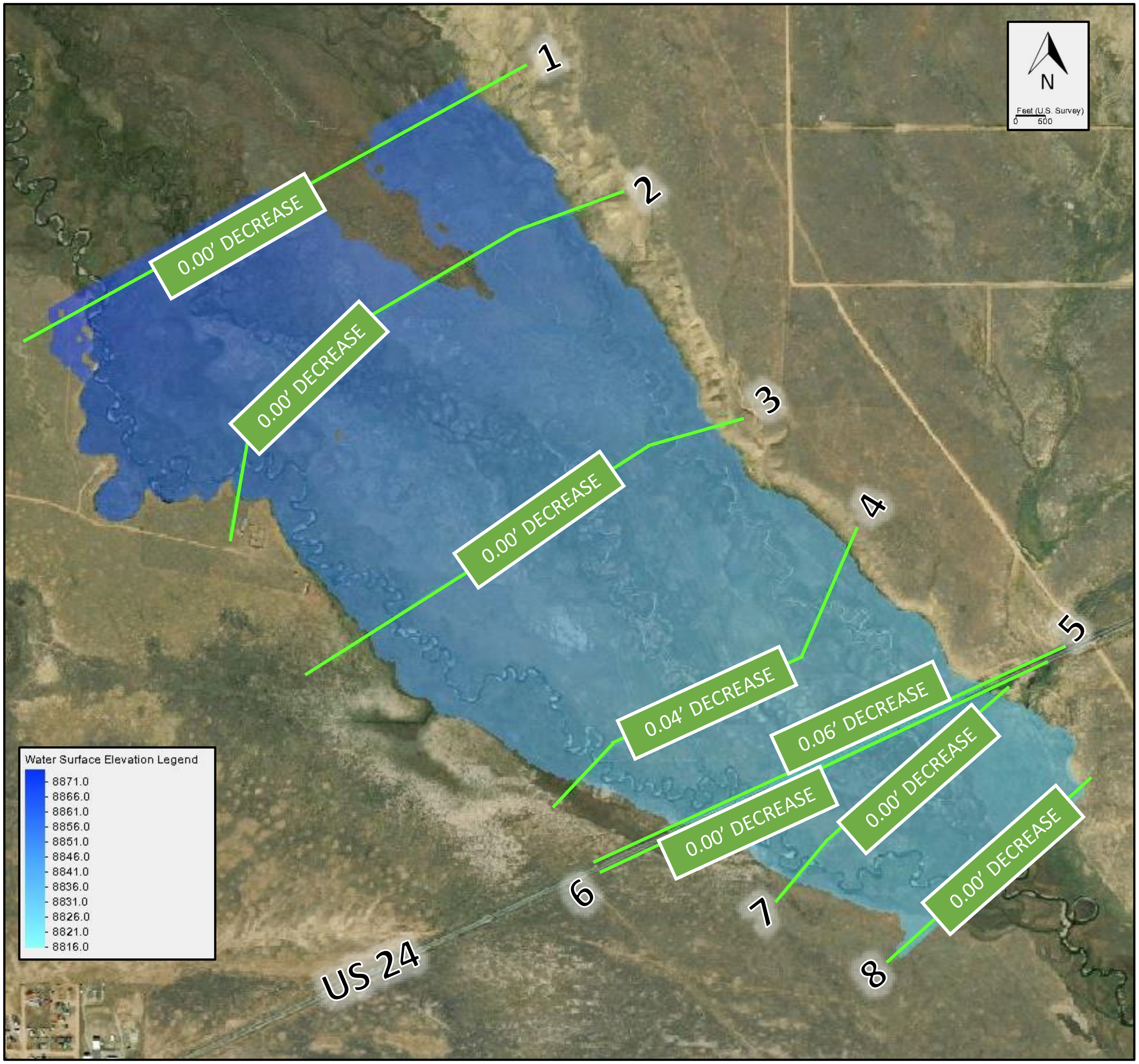
APPENDIX G WATER SURFACE ELEVATION COMPARISON GRAPHICS



WATER SURFACE ELEVATION COMPARISON – RCBC OPTION

STRUCTURE H-13-N

FIGURE 1



WATER SURFACE ELEVATION COMPARISON – ARCH OPTION

STRUCTURE H-13-N

FIGURE 2

APPENDIX H ARCH CULVERT SCOUR ANALYSIS

Hydraulic Analysis Report

Project Data

Project Title: H-13-N 100YR

Designer: Stanley Consultants

Project Date: Tuesday, January 12, 2021

Project Units: U.S. Customary Units

Riprap Analysis: Arch Culvert - Left Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the maximum velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 7 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 5.8 ft

Flow Depth at Toe of Abutment: 4.2 ft

Calculations will use either total or overbank discharges.

Total Discharge: 2514.06 cfs

Overbank Discharge: 136.44 cfs

Total Bridge Area: 389 ft^2

Setback Area: 25.08 ft^2

Maximum Channel Velocity: 6.46 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.2069

Characteristic Velocity: 6.46288 ft/s

Froude Number at the Abutment Toe: 0.555967

Abutment Coefficient: 1.02

Computed D50: 9.6304 in

Design D50 = 12 in

Thickness = 24 in

Design D50 > Computed D50

12 in > 9.6304 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS III

Riprap Class Order: 3

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Layout Recommendations

Minimum Riprap Thickness: 24 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 8.4 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

No channel used in calculations

Riprap Analysis: Arch Culvert - Right Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the maximum velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 9 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 5.8 ft

Flow Depth at Toe of Abutment: 3.5 ft

Calculations will use either total or overbank discharges.

Total Discharge: 2514.06 cfs

Overbank Discharge: 212 cfs

Total Bridge Area: 373.5 ft^2

Setback Area: 31.5 ft^2

Maximum Channel Velocity: 6.73 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.55172

Characteristic Velocity: 6.73108 ft/s

Froude Number at the Abutment Toe: 0.634306

Abutment Coefficient: 1.02

Computed D50: 10.4463 in

Design D50 = 12 in

Thickness = 24 in

Design D50 > Computed D50

12 in > 10.4463 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS III

Riprap Class Order: 3

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Layout Recommendations

Minimum Riprap Thickness: 24 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 7 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

No channel used in calculations

HY-8 Energy Dissipation Report

Scour Hole Geometry

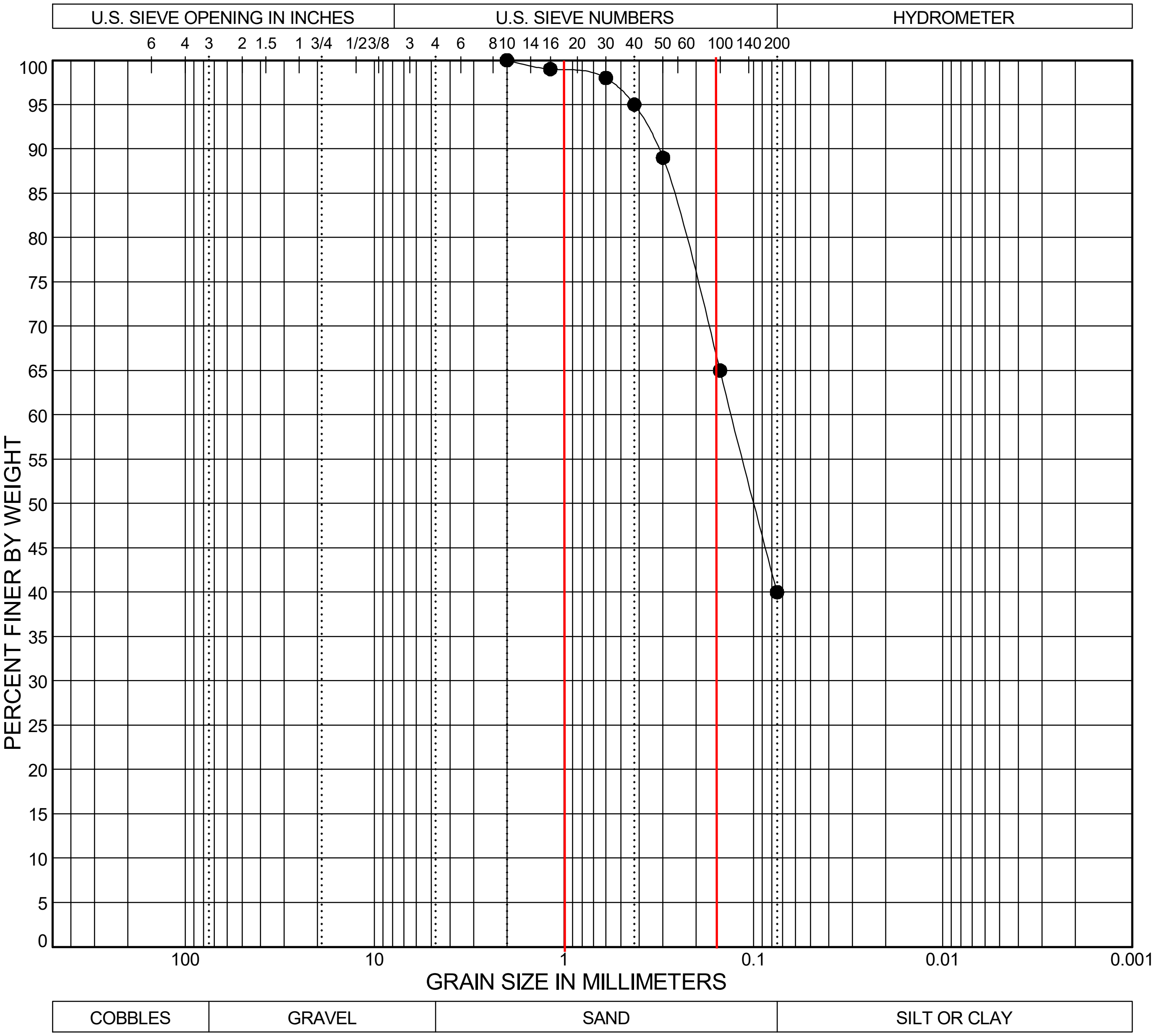
Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed Culvert	
Culvert	Box	
Flow	4915.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	24.0	ft
Culvert Height	6.0	ft
Outlet Depth	6.00	ft
Outlet Velocity	15.31	ft/s
Froude Number	1.10	
Tailwater Depth	10.26	ft
Tailwater Velocity	9.39	ft/s
Tailwater Slope (SO)	0.0000	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.00	min
Cohesion	Noncohesive	
D16 Value	0.18	mm
D84 Value	1.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	2.36	
Scour Hole Dimensions		
Length	-1.#IO	ft
Width	-1.#IO	ft
Depth	-1.#IO	ft
Volume	-1.#IO	ft^3
DS at .4(LS)	-1.#IO	ft
Tailwater Depth (TW)	10.256	ft
Velocity with TW and WS	-1.#IO	ft/s

HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed Culvert	
Culvert	Box	
Flow	4915.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	24.0	ft
Culvert Height	6.0	ft
Outlet Depth	6.00	ft
Outlet Velocity	15.31	ft/s
Froude Number	1.10	
Tailwater Depth	10.26	ft
Tailwater Velocity	9.39	ft/s
Tailwater Slope (SO)	0.0000	
External Dissipator Data		
External Dissipator Category	Streambed Level Structures	
External Dissipator Type	Riprap Basin	
Restrictions		
Froude Number	<3	
Input Data		
Condition to be used to Compute Basin Outlet Velocity	Best Fit Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.649 ft	
D50 of the Riprap Mixture	0.649	ft
DMax of the Riprap Mixture	1.000	ft
Results		
Brink Depth	6.000	ft
Brink Velocity	15.306	ft/s
Depth (YE)	6.000	ft
Riprap Thickness	1.500	ft
Riprap Foreslope	2.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.016	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.108	
D50/YE Check	D50/YE is OK	
Basin Length (LB)	96.000	ft
Basin Width	88.000	ft
Apron Length	24.000	ft
Pool Length	72.000	ft
Pool Depth (HS)	1.309	ft
TW/YE	1.709	
Tailwater Depth (TW)	10.256	ft
Average Velocity with TW	1.980	ft/s
Critical Depth (Yc)	2.636	ft
Average Velocity with Yc	8.963	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	11.753	ft/s
Size	0.900	ft
Distance: 2 LB		
Velocity	6.545	ft/s
Size	0.279	Ft
Distance: 3 LB		
Velocity	4.351	ft/s
Size	0.123	ft
Distance: 4 LB		
Velocity	3.256	ft/s
Size	0.069	ft

APPENDIX I GEOTECHNICAL INFORMATION



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines: %Silt	%Fines: %Clay
● **H-13-N Scour**	**0.0**	**A-4 (0)**	**SM**	**NV**	**NP**	**NP**	**0.0**	**60.0**	**40.0**	

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

SIEVE ANALYSIS

FIGURE S- 7

Project No. 220-063 Date: 11-24-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Scour Test Results
Structure H-13-N

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/24/20